The WELDING JOURNAL

MARCH 1953

IN THIS ISSUE

Technique for Eliminating Back Rings in Piping 205
Resistance Welding of Dissimilar Metals to Magnesium 217
Unity in Welded Steel Construction 225
Groove Cutting for the Shop 232
Temperature Distribution During Flash Welding 113-s
Notch Impact Tests of Weld Metal at Low Temperature 122-s
Weld Metal Area in Hardenable Steels 125-s
Decomposition of Austenite in Low-Alloy Carbon and Weld Metal 134-s
Effects of Carbon, Oxygen and Nitrogen on Welds in Titanium 139-s
Table of Contents 205
Index to Advertisers 286

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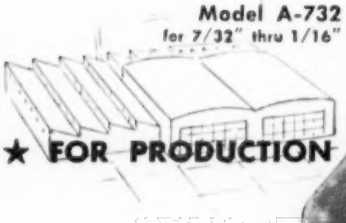

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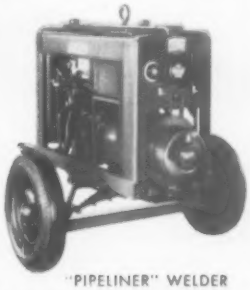

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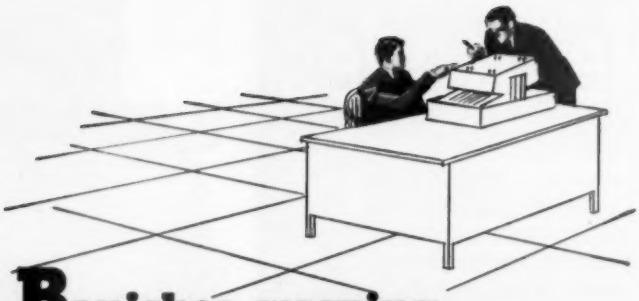

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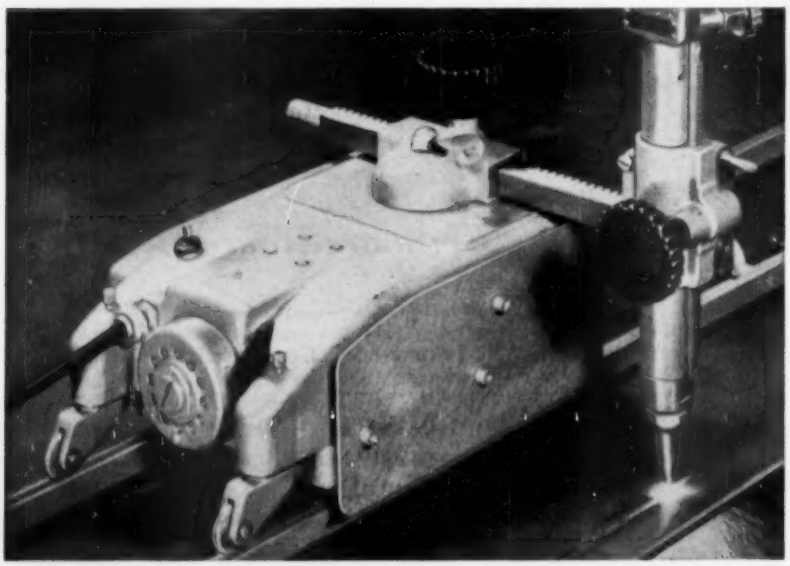

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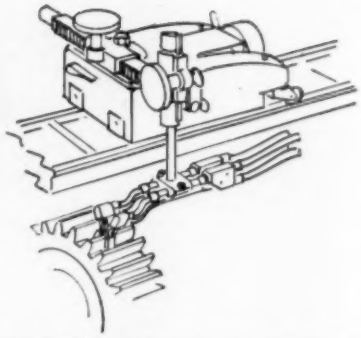

Fig. 2—Flame-treating work requires precise control of applied heat. The CM-45, with suitable apparatus, assures you of efficiency and uniformity on every job.

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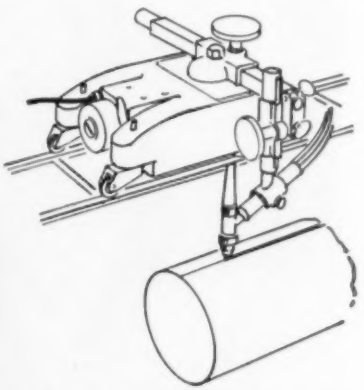

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TECHNICAL PAPERS, ITEMS AND REPORTS

Inert-Arc Welding Technique for Eliminating Backing Rings in Piping, by R. A. Mueller and W. B. Root ... 205
Discussion by H. S. Blumberg and Charles Diehl ... 214
Authors' Reply ... 215
Current Welding Literature ... 216
Resistance Welding of Dissimilar Metals to Magnesium for Electrical Connections, by Paul Klain and H. W. Croisant ... 217
Unity in Welded Steel Construction, by Robert S. Hale ... 225

PRACTICAL WELDER AND DESIGNER

Watch Expansion and Contraction During Welding, by B. H. Higgs ... 230
Combination Welding and Forming Machine, by John Maloney ... 231
Groove Cutting for the Shop, by R. G. Householder ... 232
Brazing Methods for Refrigeration Units, by A. L. Johnson ... 235
Longer Life for Truck Center Castings ... 237

SOCIETY AND RELATED EVENTS

Society News ... 238
News of the Industry ... 239
Personnel ... 252
New Products ... 254
New Literature ... 265
Section News and Events ... 268
Employment Service Bulletin ... 280
Current Welding Patents ... 282
List of New Members ... 284
Index to Advertisers ... 286

WELDING RESEARCH SUPPLEMENT

Temperature Distribution During Flash Welding of Steel—Part II, by E. F. Nippes, W. F. Savage, S. S. Smith, J. J. McCarthy and G. Grotke ... 113-s
Notch Impact Tests of Weld Metal at Low Temperatures, by M. Lefèvre and J. Lemoine ... 122-s
The Role of Weld Metal Area in Welding Hardenable Steels, by C. R. McKinsey and J. F. Collins ... 125-s
The Corneille Bridge in Rouen, by J. Velitchkovitch and A. Schmid ... 131-s
Decomposition of Austenite in Low Carbon, Ni, No, Steel Weld Metal, by E. F. Bailey and W. J. Harris, Jr. ... 134-s
Effects of Carbon, Oxygen and Nitrogen on Welds in Titanium, by D. C. Martin ... 139-s
Netherlands Welding Society ... 154-s
The Weldability of Austenitic Manganese Steels, by F. Danhier ... 155-s
Studies of the Crack Sensitivity of Aircraft Steels, Discussion by J. Koziarski ... 157-s
Authors' Reply ... 159-s
Discussion by E. C. Rollason and R. R. Roberts ... 159-s
Authors' Reply ... 160-s

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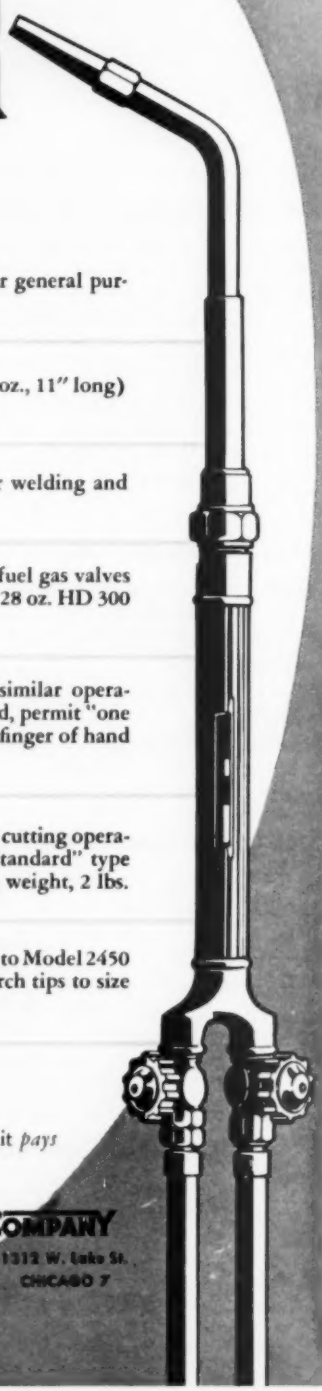

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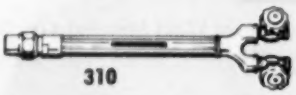 310	A medium weight and length torch (21 oz., 11" long) for all around use.
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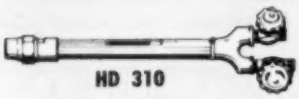 HD 310	Heavy duty models with high capacity fuel gas valves for large gas flows. HD 310—11" long, 28 oz. HD 300—14" long, 32 oz.
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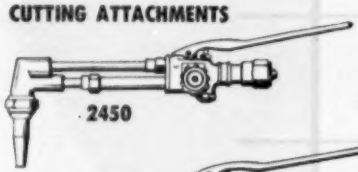
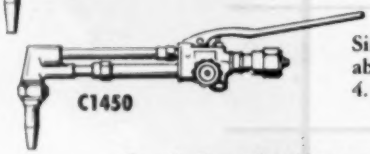
 2450	Handles a full range of general purpose cutting operations up to approximately 8". Uses "Standard" type cutting tips up to size 5. Length is 13"; weight, 2 lbs.
 C1450	Similar in size, weight and construction to Model 2450 above, but designed for smaller "C" torch tips to size 4. Cuts to approximately 6".

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volume 32 March 1953 number 3

Inert-Arc Welding Technique for Eliminating Backing Rings in Piping

Integral metal backing rings have several shortcomings in weld fabricated piping. The authors describe numerous experimental and actual shop welds on a variety of pipe materials which successfully demonstrate the practicability of the inert-arc welding method

by R. A. Mueller and W. B. Root

METAL backing rings are widely used in butt-welded joints of piping structures which are inaccessible for grinding or welding from the underside of the joint. Backing rings primarily prevent weld drippings, spatter and flux slag from entering the pipe, and are designed to provide solid metal against which the weld metal of the first bead is deposited. They are also intended to aid in obtaining full penetration and fusion at the root of butt welds made in all positions of welding on pressure piping. Although many types of backing rings are manufactured for pipe fabrication, the most commonly used are flat rings rolled from strip material for ordinary applications and machined tapered rings for critical service such as steam power piping. These two types are illustrated in Fig. 1. It should be realized that these metal backing rings are actually fused to the pipe during the welding process and serve as an integral part of the welded joint.

Many problems have been encountered with the use of metal backing rings, the most troublesome being the necessity for accurate fitting of the ring with the ID of the pipe being joined. Accurate fit-up is required to prevent the formation of weld metal cracks which originate at the notch or separation between the backing ring and the inside surface of the pipe. It has been our experience as well as that of many other fabricators that integral metal backing rings in *ferritic* materials being metal arc welded with conventional coated electrodes require a very good fit-up, otherwise root cracks are apt to develop as illustrated in Fig. 2. These root cracks are considered very serious and undesirable where the weldment may be subjected to conditions of high imposed stress such as that caused by thermal quenching of water particles in a desuperheating steam cycle (see Fig. 3). Hence under certain conditions of thermal shock, a slight root crack can extend and lead to ultimate failure of the joint. Great concern should also be given to services where fatigue and the like may be prevalent.

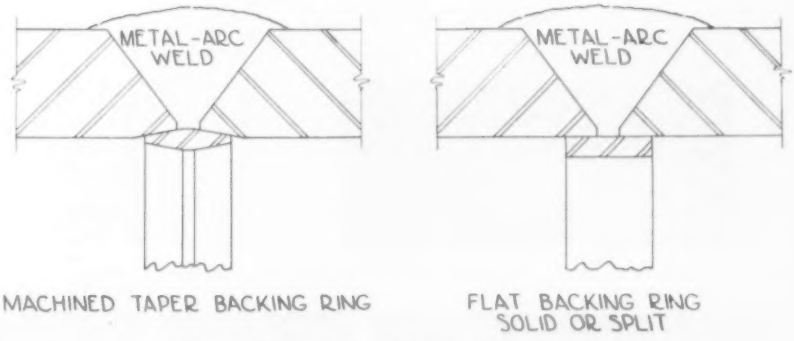
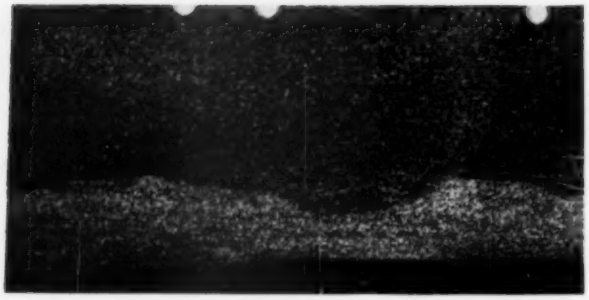


Fig. 1 Commonly used metal backing rings

In order to fully appreciate the problem of pipe welding and fit-up of backing rings, it should be realized that pipe specification were originally prepared to control the OD dimension for threading purposes, since in the early days of low pressures and temperature of operation, threaded joints in pipe was the common practice. The outgrowth of welding sponsored by the higher operating condition of today's industry has not altered the tolerances in the manufacture of commercial seamless steel pipe. The close control of OD dimensions and the mill tolerance of plus or minus 12½% wall thickness reflects in a variation of the inside diameter of the pipe. The heavier the pipe wall thickness, the greater the possible variation in the ID dimension.

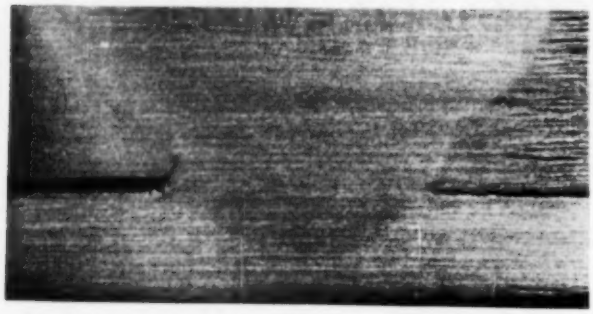
R. A. Mueller is General Foreman, Pipe Fabrication, and **W. B. Root** is Supervising Engineer, Welding Engineering Laboratory, Crane Co., Chicago, Ill.

Presented at the Thirty-Third National Fall Meeting, AWS, Philadelphia, Pa., week of Oct. 20, 1952. Closing date for discussion May 15, 1953.



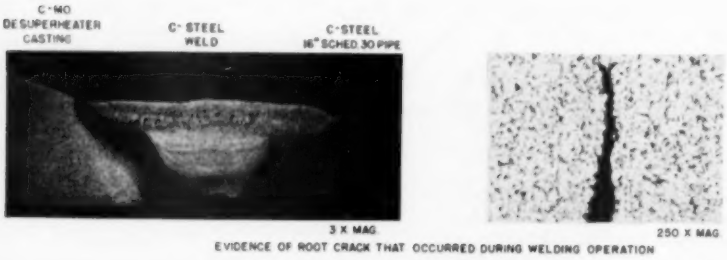
GOOD BACKING RING FIT-UP

PIPE JOINT IN ½ % CHROME ½ % MOLY ALLOY STEEL 8⅔ X MAG



POOR BACKING RING FIT-UP REVEALING ROOT CRACK

Fig. 2 Example of root cracking with poor fit-up of backing and ferritic base metal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C-STEEL 16" SCHED 30 PIPE
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250 X MAG.
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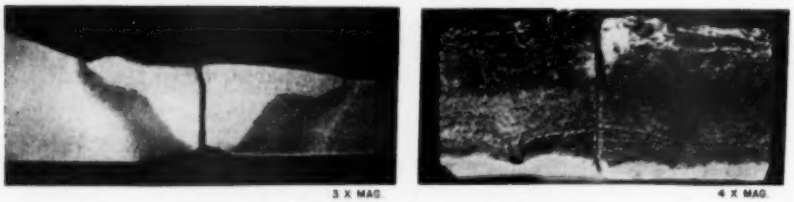


Fig. 3 Evidence of root crack propagation in weld joint causing ultimate failure after 70,000 hr of steam service at 800° F

Matching of pipe ends for close fitting backing rings is understandably a major issue and has led to many theories and formulas for calculating backing ring dimensions.

To further complicate the picture of welding pipe with backing rings, it has been experienced (Fig. 4) that root cracks can exist in columbium bearing austenitic stainless steels even though the fit-up of the backing ring is close. Also when the welding joint is placed in restraint by external holding of the pipe, a more severe condition of cracking exists at the junction of the backing ring and pipe end as shown in Fig. 5. Investigations conducted to date employing conventional metal arc welding techniques seem to hold no ready solution that will completely eliminate the crack that extends from the virtual crack formed by the backing ring and the ID surface of the austenitic pipe being joined.

Besides the backing ring presenting an undesirable stress raiser at the root of the welding joint due to its inherent clearance,

Fig. 4 Type 347 weld in 18Cr – 8Ni Cb + Ta parent metal showing root bead cracks despite good fit-up of backing ring

many services prohibit their use such as in the oil industry where "coking" has shown complete failures of welded joints.[1] Hydrocarbon gas that is entrapped in any crevice and remains relatively dormant, "cracks" at high temperatures with the formation of carbon and frequently exerts sufficient pressure to distort metal beyond its yield point. The use of backing rings in the chemical industry is definitely prohibited where contamination is not allowed. In small diameter piping, usually considered as 2 in. and under, the use of a backing ring may be detrimental due to its obstruction to flow. In steam generating systems where sectional hot bent and welded fabrications are finally cleaned by sandblasting, the silica particles that may be entrapped within the backing clearances can become dislodged in service and cause serious valve and turbine problems.

Thus we see that integral metal backing rings are in many instances an undesirable feature. Many attempts have been made in the past by numerous investigators to eliminate the use of integral backing by employing removable metal backing structures such as retractable copper rings, but certain shortcomings were encountered to prevent a general application in the piping field. Other forms of backing that do not form an integral part of the welding joint such as ceramic materials as a backing have been experimented with, but to date have not gained popular acceptance in the pressure piping field.[2]

DEVELOPMENT OF INERT ARC WELDING IN THE PIPING FIELD

To the person who may be unfamiliar with the inert-gas-shielded arc-welding method,[3, 4] it may be briefly defined as a welding process in which the welding arc is maintained between a virtually nonconsuming electrode and workpiece, and the arc is shielded by a monatomic inert gas. The inert gas, usually argon or helium, serves to protect the molten pool of weld metal and electrode from the ambient atmosphere, as well as assisting ion-

ization in the arc. The most commonly used electrode is tungsten in the pure form or with thorium added. This process should not be confused with inert-gas-shielded metal-arc welding where the tungsten electrode is replaced by a continuously fed wire which becomes consumed as filler metal during the welding operation.

The inert-gas-shielded arc-welding process (hereinafter referred to as inert arc welding) has since 1940 become a notable fusion welding method. Its application appears to be unlimited and has overtaken other welding processes for certain welded structures because of its many outstanding advantages. Since approximately 1947, the inert-arc welding process has been successfully used to fabricate thin wall tubing of numerous metal compositions in both ferrous and nonferrous classes. The general application of this tubing has been in the chemical industry where general requirements of no crevices for fear of contamination of flowing media within the piping structure preclude the use of integral backing rings.

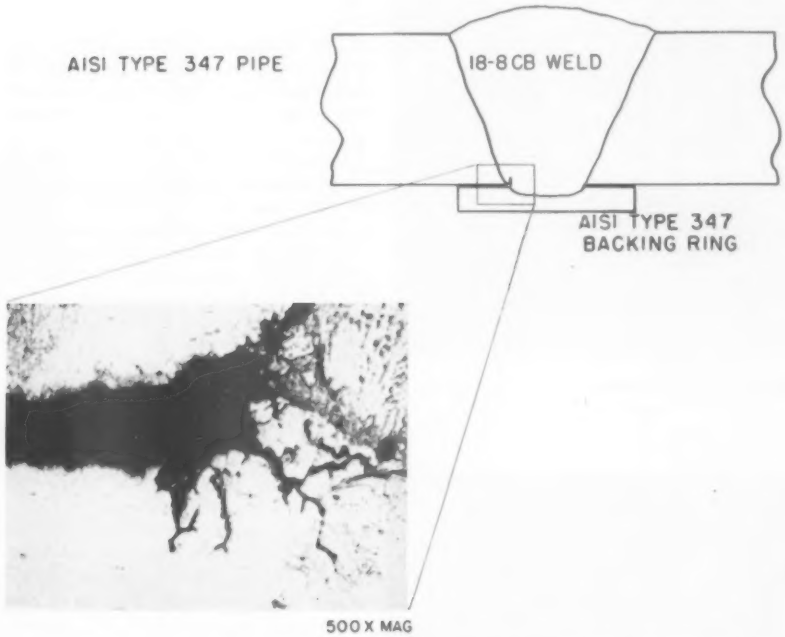


Fig. 5 Root crack in Type 347 pipe joint made with a backing ring and under external restraint

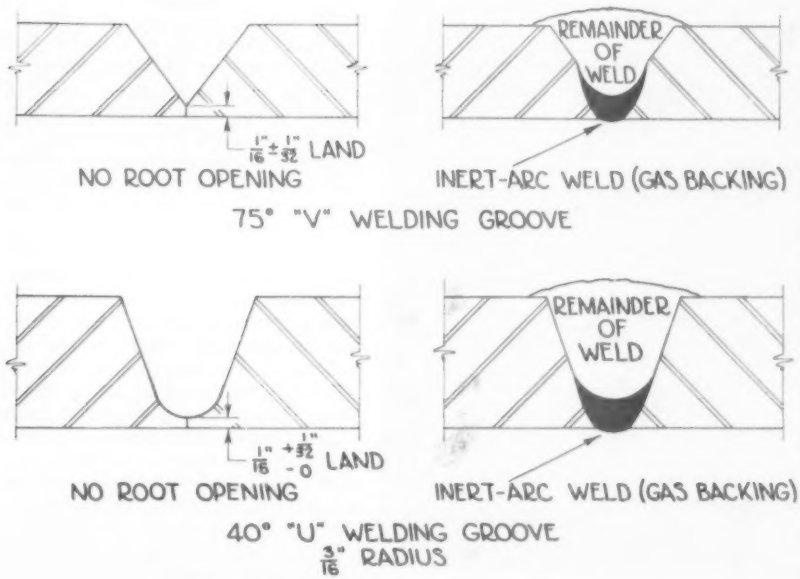


Fig. 6 Groove design for inert-arc first pass

INERT ARC WELDING OF THIN-WALL TUBING

The inert arc welding of such tubing has proved to be an indispensable method at Crane Co. for fabricating commercially pure nickel. Monel (nickel-copper alloy), Hastelloy (nickel-molybdenum-iron alloy) and austenitic stainless steel (chromium-nickel-molybdenum alloy) in diameter sizes $\frac{1}{2}$ to 18 in. with wall thicknesses notably $\frac{1}{8}$ to $\frac{1}{4}$ in., inclusive. The inert-arc welding process enabled a good degree of corrosion resistance, X-ray and vacuum tight (helium-mass spectrometer tested) welds, and smooth appearing welds with 100% fusion and penetration at the root with a maximum projection into the pipe of $\frac{1}{16}$ in. These requirements have been substantiated by the fact that over 12,000 welds have been produced in shop fabrication and approved by rigid inspection.

The inert-arc welded joints were made by butting the pipe without any root opening and fusing the root portion without adding filler metal as illustrated in Fig. 6. The remainder of the weld could be completed by any suitable welding method. However, it was found most economical to finish the entire weld by means of the inert arc welding for tubing whose wall thickness did not exceed $\frac{1}{4}$ in. In such cases, filler metal matching the parent metal composition was used in a manner similar to the conventional oxy-acetylene gas welding techniques. Figure 7 illustrates a typical setup of inert arc welding the thin-wall tubing.

The inert arc welding can be accomplished with direct current motor-generator sets, direct-current selenium rectifiers or with alternating-current transformers. Since the majority of both shop and field pipe fabricators are equipped with direct current equipment, certain preference is given to this source of welding power. Water-cooled welding torches are available in a lightweight design which permit easy handling for circumferential pipe welds. Water-cooling units can be easily constructed or purchased for circulating conditioned water through the torches. Refinements such as automatic starting and stopping of the water and inert-gas flow through the torch when the welding arc is established can be included in the welding setup but are not mandatory. Packaged units, including the welding machine and all accessories, can be purchased in today's market for a very small capital investment. The use of thoriated-tungsten electrodes (i.e., tungsten with at least 1% thorium added) in

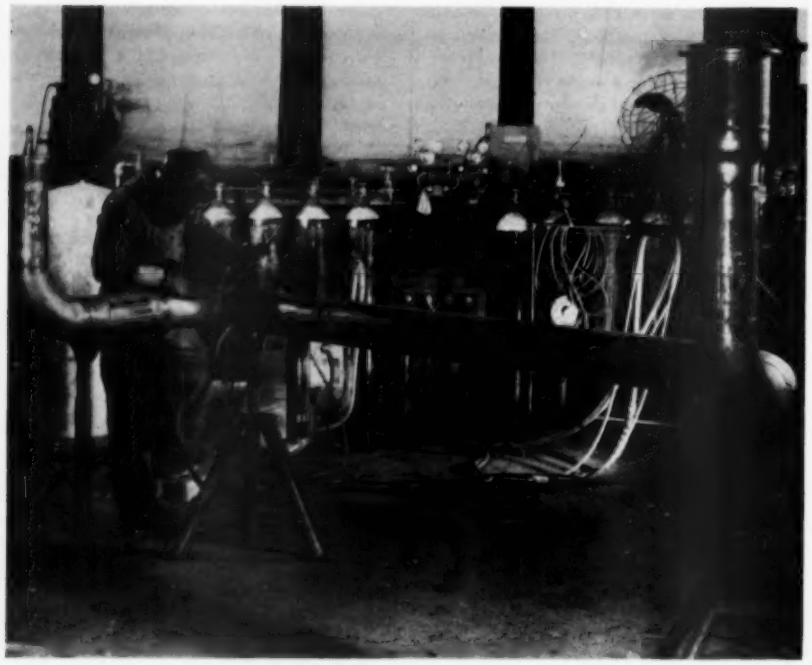


Fig. 7 Inert arc welding thin wall tubing

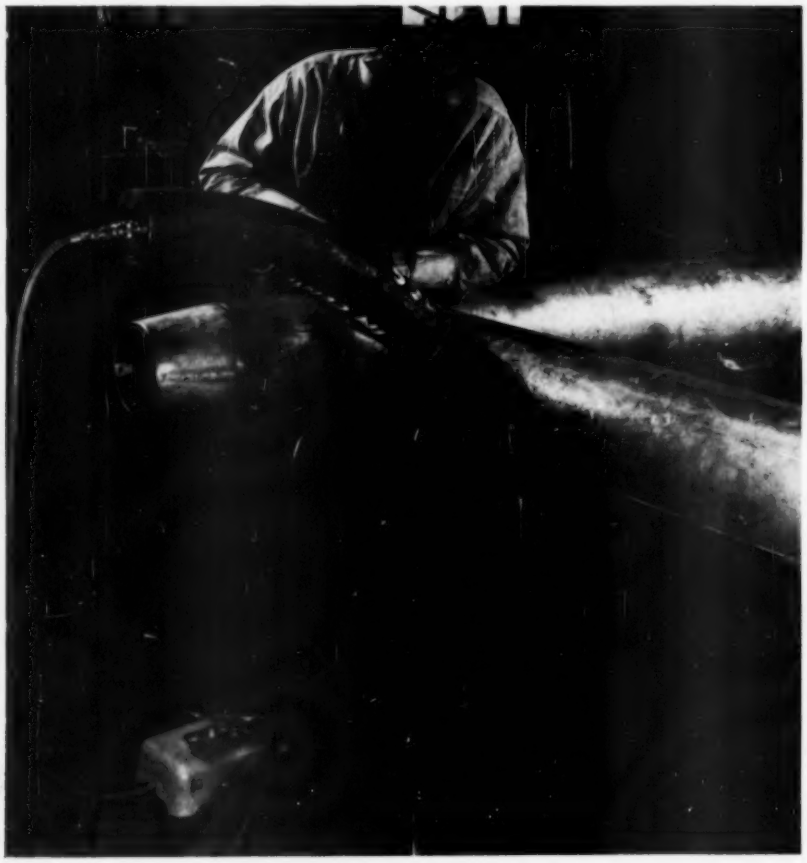


Fig. 9 Purging the pipe interior with an inert gas during inert arc welding

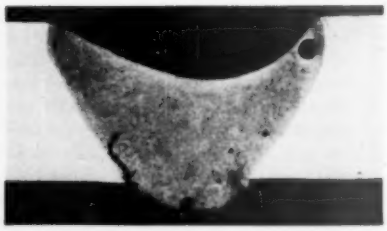


Fig. 8 Inert arc welding Monel tubing without protective backing

lieu of straight tungsten simplifies the welding setup by enabling the ignition of the welding arc directly on the workpiece and provides smoother arc characteristics with less "sticking" tendencies.

In the development of inert arc welding the stainless variety of thin-walled tubing, it was found that the underside of the welding joint must be protected from oxidation during welding, otherwise root cracks usually developed as illustrated in Fig. 8. The protection was very simply carried out by means of purging the pipe interior with an inert gas (either helium or argon) as shown in Fig. 9. A slight pressure in excess of atmospheric was employed and welding was initiated when the air was displaced from the area of the welding joint. On certain fabrications where considerable length of tubing was involved, a simple fixture was designed to confine the inert gas protection to only the area being welded. Figure 10 illustrates a typical fixture which is inserted into the piping structure for the purpose of conserving the purging gas on long or large assemblies.

USE OF INERT-ARC FIRST PASS TECHNIQUE FOR PRESSURE PIPING

The successful fabrication of light wall stainless steel and nonferrous tubing by inert arc welding suggested a logical method to eliminate backing rings in pressure piping. Backing rings were no longer of necessity since the interior of butt weld joints properly made by inert arc welding displayed full penetration and fusion, no weld drippings undercut or foreign matter. The transition from light-wall tubing of the stainless variety to heavy-wall chromium-molybdenum alloy steel pipe required many welding tests for full evaluation of a suitable welding procedure. In the investigation, emphasis was placed on weld joint design, preheat for welding, type of shielding gas, welding current characteristics, position of welding and purging of the weld underside.

Welding tests were performed on pipe ranging in sizes from 3-in. diam schedule 40 ($^{7}/_{32}$ in. thick) to 10-in. OD and 1 in. thick. Short-length pipe samples were prepared using both of the present standard welding bevels, namely the 37$^{1}/_{2}$-deg

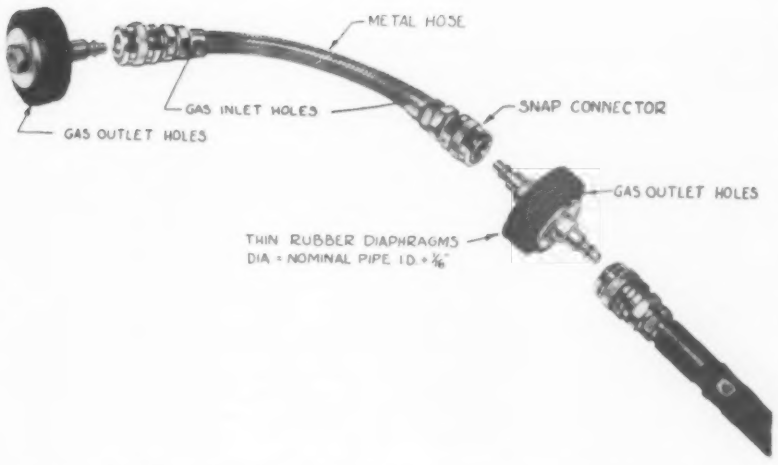


Fig. 10 Flexible gas purging fixture to protect the underside of inert arc welds made in piping

straight bevel and the 20 deg "U" groove welding bevel. Inert gas for the welding tests included argon and helium. Weld samples were made with and without argon purging of the weld underside, and in all positions of pipe, such as horizontal rolled, horizontal fixed and vertical. Upon completion of the inert-arc first pass, the welds were finished with the usual metal-arc welding practice.

Testing of the completed welds consisted mainly of visual examination of the weld underside and guided jig root bend tests. The use of radiographic, magnetic particle, and liquid penetrant inspection for root fusion was briefly studied. The determination of hardness distribution in the weld root area and metallographic examination of the inert-arc weld structure was also employed in the investigation.

Figure 11 summarizes the various welding tests and the results obtained. The results indicated that with proper technique, fully penetrated and fused welds capable of passing the prescribed root-bend test (ASA Pressure Piping and ASME Boiler Code requirements) were readily obtained. In addition to weld soundness and good bend properties, a major criteria for satisfactory welds was the proper contour of the underside of the root bead. Under certain conditions when welding in positions other than downhand, the inert-arc root bead tended to sag, resulting in a concave or hollow weld underside. The depression thus produced was considered undesirable due to the reduction of the effective pipe wall thickness at the weld joint. More favorable conditions produced weld root beads essentially flush with the inside surface of the pipe. The factors which determine the weld underside condition are self evident in Fig. 12 which illustrates both acceptable and unacceptable weld root beads. For example, when welding heavy-wall pipe scarfed with a straight "V" bevel in the overhead position, the combined effect of weld shrinkage and gravity caused the root bead to sag. The sagging tendency was noted also in the vertical position of pipe (horizontal weld bead), but to a lesser degree. Welds accomplished with the straight V bevel in the horizontal rolled or the top half of the horizontal fixed position displayed root beads either flush with the pipe inside surface or having a slight underhang.

Use of the U welding groove as shown in Figs. 12 and 13 virtually eliminated the sagging tendency, so that with proper welding technique flush root beads were produced regardless of position of welding or pipe wall thickness. In addition, the U groove permitted lower welding currents, resulting in a smaller, more easily controlled weld pool, having less tendency for crater crack formation. With the V groove, more skillful technique was required in properly finishing the weld bead to prevent crater cracking.

The details of joint design, machining dimensions and accuracy of fit-up received considerable attention in the investigation. Based on previous experimental work, it was believed that almost perfectly matched pipe welding ends having equal land heights were required for uniform penetration and root fusion. To obtain consistent results, it was thought necessary to taper bore the pipe ends to specified uniform dimensions according to pipe diameter size and wall

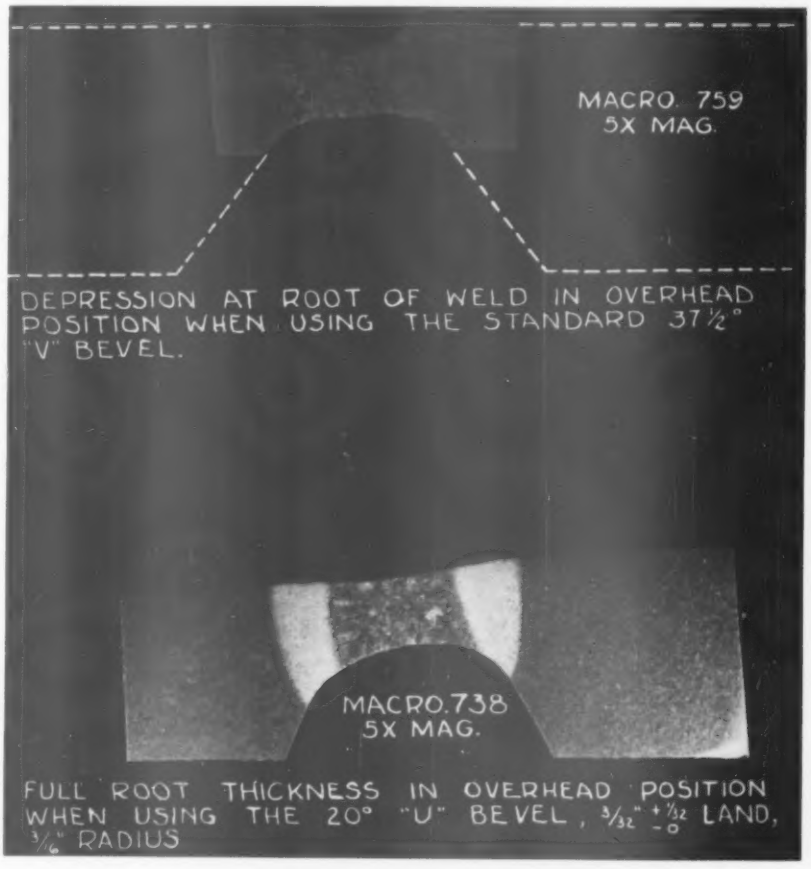

MACRO. 759
5X MAG.
DEPRESSION AT ROOT OF WELD IN OVERHEAD POSITION WHEN USING THE STANDARD 37½° "V" BEVEL.
MACRO.738
5X MAG.
FULL ROOT THICKNESS IN OVERHEAD POSITION WHEN USING THE 20° "U" BEVEL, 3/32" +1/32 -0 LAND, 3/16" RADIUS

Fig. 12 First pass welded by inert-arc process using inert-gas purging

Sample Description			Welding Bevel			Test Ident. No.	Position of Welding	Pre-heat °F min.	Gas Shielding		Under-side Purging Gas	Current Characteristics (Direct current, STR polarity)			Weld Underside Condition		Weld Metal Defects	Stress Relief °F	Root Bend Test	Remarks
Material	Pipe Diam.	Pipe Thick	Type Groove	Land Height	Angle Bevel				Type Gas	Flow Rate C.F.M.		Tungsten	Amps.	Volts	Penetration and Fusion	Inside Contour of Weld Bead				
Carbon steel grade "A" A106	3"	1/2"	V	1/16"	37 1/2°	21-22 23	Top half horiz. fixed	None	Helium	1.25	Argon	1/16"	70		All welds complete penetration and full root fusion.	Flush with inside surface with argon purging. Weld made without argon purging rough and with many hollow spots.	None	None	Root bend tests (four from weld No. 28) satisfactory.	Satisfactory results in horiz. fixed position (top half only) with both machined and flame cut and ground end preparations. Weld underside smooth except when made without argon purging.
				1/32" to 3/32" (A)	45°	24-25		None	Helium	1.25	Argon	1/16"	70							
				1/16" to 3/32" (A)	45°	26		None	Helium	1.25	None	1/16"	70							
				1/16" to 3/32" (A)	45°	27-28		None	Helium	1.25	Argon	1/16"	70							
Carbon steel grade "A" A106	6"	1/2"	V	1/16"	37 1/2°	29	Top half horiz. fixed	None	Argon	0.30	Argon	3/32"	200	13	Both welds complete penetration and full root fusion.	Flush with inside surface.	None	None	No bend tests made	Satisfactory results with argon and Helium with "V" groove in top half horiz. fixed position.
						30		None	Helium	0.80	Argon	3/32"	120	16						
Carbon steel grade "B" A106	6"	3/8"	U	3/8"	20° 3/16" R	19A	Vertical	None	Argon	0.30	Argon	3/32"	140	13	Both welds complete penetration and full root fusion.	Flush in vertical weld. Horizontal fixed welds same as tests 11 to 14.	None	None	Root bend tests satisfactory	Satisfactory results obtained in vertical and horizontal fixed positions. Welds completed by metal-arc.
						19B	Horiz. fixed	None	Argon	0.30	Argon	3/32"	140	13						
2 1/4 %Cr 1%Mo	7"OD	3/8"	V	1/16"	37 1/2°	1	Horiz. rolled	None	Argon	0.20	None	3/8"	280	18	All welds complete penetration and full root fusion.	Bet. 1/32" and 1/16" weld underhang. Bottoms of unpurged welds were rough and uneven.	None	1300	All root bend tests (two from each weld), satisfactory	No cracking or difficulties due to lack of preheat. Weld completed by metal-arc. Welds not gas purged, slightly oxidized.
						2		500	Argon	0.20	None	3/8"	250	18						
						3		None	Argon	0.20	Argon	3/8"	280	18						
						4		500	Argon	0.20	Argon	3/8"	250	18						
2 1/4 %Cr 1%Mo	7"OD	3/8"	V	1/16"	37 1/2°	5	Horiz. fixed	None	Argon	0.20	Argon	3/8"	285	17	All welds contain areas of incomplete penetration	Hollow at bottom of pipe (overhead position). Flush or slight underhang on sides and top.	Tendency for cracks due to incomplete penetration.	None	None	Hollow due to shrinkage of weld metal unavoidable with "V" groove in overhead position. Weld tests discontinued after poor first pass results.
			U	3/32"	20° 3/16" R	6		None	Argon	0.20	Argon	3/32"	175	15						
			V	1/16"	37 1/2°	7		None	Argon	0.30	Argon	3/32"	250	20						
			V	1/16"	37 1/2°	8		None	Helium	1.00	Argon	3/32"	130	20						
2 1/4 %Cr 1%Mo	7"OD	3/8"	U	3/32"	20° 3/16" R	11	Horiz. fixed	None	Argon	0.30	Argon	3/32"	165	15	All welds complete penetration and full root fusion.	Slight hollow at bottom of pipe (overhead position). Flush or slight underhang on sides and top.	None	1300	All root bend tests (2 from each weld) satisfactory. Also 2 side bends, tests 13 and 14.	Equally good results with Argon and Helium for welding first pass with "U" groove in horiz. fixed position. Completed by metal-arc welding.
						12		None	Helium	1.00	Argon	1/16"	90	18						
						13		None	Argon	0.30	Argon	3/32"	165	12						
						14		None	Helium	1.00	Argon	1/16"	90	14						
2 1/4 %Cr 1%Mo	10"OD	1"	U	1/16"	20° 3/16" R	35	Vertical	400	Helium	1.00	Argon	3/32"	140	13	All welds complete penetration and full root fusion.	Flush with inside surface.	None	1300	All root bend tests satisfactory	Satisfactory results obtained in vertical and horizontal fixed positions. Welds completed by metal-arc.
							Horiz. fixed	400	Helium	1.00	Argon	3/32"	140	13						
4-6%Cr 1/2%Mo	6"	3/8"	U	3/32"	20° 3/16" R	17A	Vertical	400	Argon	0.30	Argon	1/16"	125	14	Both welds complete penetration and full root fusion.	Flush in vert. weld. Horiz. fixed welds same as tests 11 to 14.	None	1350	Root bend tests satisfactory	Satisfactory results in vert. and horiz. fixed positions. Welds completed by metal-arc.
						17B	Horiz. fixed	400	Argon	0.30	Argon	1/16"	120	13						
Type 347 Stainless Steel	8"	1/2"	V	1/16"	37 1/2°	33	Horiz. rolled	None	Helium	1.00	Argon	3/32"	125	15		Flush—max. 1/16" underhang.	None	None	Root bend tests satisfactory	Satisfactory results in horiz. rolled & top half horiz. fixed positions. Welds completed by metal-arc.
						34	Top half Horiz. fixed	None	Helium	1.00	Argon	3/32"	125	15						
Type 347 Stainless Steel	6"	1/4"	U	3/32"	20° 3/16" R	31	Vertical	None	Helium	0.50	Argon	1/16"	50	14		Flush with inside surface	None	None	Root bend tests satisfactory	Satisfactory results in vert. and horiz. fixed positions. Welds completed by metal-arc.
						32	Horiz. fixed	None	Helium	0.50	Argon	1/16"	50	14						

(A) Welding bevel prepared by oxy-acetylene torch cutting and light grinding. Machined bevels on all other samples. Top half-horizontal fixed position defined as pipe fixed in a horizontal plane and welded only in the upper half position from the side to top. The pipe is turned over 180° so that welding from the side to the top completes the circumferential weld, thus eliminating the overhead position of welding.

Fig. 11 Summary of test results—inert arc welding first pass of pipe butt weld joints

thickness, similar to established machining standards for tapered backing rings. However, in the course of the investigation it became apparent that regular commercial practice for the preparation of welding bevels on pipe, fittings and valve ends would be quite satisfactory. For best results, however, the amount of offset between mating welding lands should be held to a minimum, preferably not greater than $^1/_{16}$-in. total on the diameter. Provisions should be made for the correction of larger offsets due to variation in pipe wall thickness, eccentricity or pipe out-of-round condition. While the present standard ASA pipe welding bevels are suitable for inert arc welding the first pass, a heavier than standard welding land is favored for the U bevel to prevent "burn through" of the fused lands during subsequent metal arc welding.

In order to determine the suitability of the inert-arc first pass technique on pipe material having wall thicknesses greater than 1 in., a special test was made on 3-in. thick plate material. The plates were scarfed with the standard 20-deg. U bevel to 2-in. thickness and from 2 to 3 in. with a 10-deg. bevel. A standard inert-arc welding torch was employed to butt weld the plates in the flat position as shown in Fig. 14. No difficulty was experienced in making the weld since the bottom of the groove was readily accessible and visible during welding.

Although inert arc welding of the root bead is not difficult to accomplish, the success of the operation depends largely upon the skill of a trained welding operator. Strict adherence to proper technique, correct current settings and the ability to judge the amount of penetration (not visually apparent during welding) are of greatest importance. The technique to be employed is essentially the same regardless of pipe wall thickness, type of welding groove or position of welding.

Equally satisfactory results were accomplished in the welding tests with either argon or helium-shielding gas. Figure 15 illustrates guided jig bend tests from comparable butt welds made with the two gases in $^5/_8$-in. thick, $2^1/_4$% chrome–1% molybdenum tubing.

Protection of the weld underside from the atmosphere during inert arc welding of the first pass is considered a worth-while precaution. Without gaseous protection, the weld underside tended to scale slightly and assumed a very rough and uneven appearance marked by surface depressions and voids. In contrast, the use of purging assured a smooth, clean weld underside free of all defects. Figure 16 is a direct comparison of the inside surface appearance of welds made with and without inert-gas purging. Despite the fact that purging was omitted in the welding test of $2^1/_4$% chrome–1% molybdenum steel pipe, the welds satisfactorily passed the guided jig root-bend test (Fig. 17).

Fig. 13 Appearance sample showing inert-arc fused root and completed metal arc welds made in the horizontal fixed and vertical positions of welding; 10-in. diam x 1-in. thick $2^1/_4$% Cr – 1% Mo pipe

Fig. 14 Inert arc welding first pass in 3-in. material using a standard torch

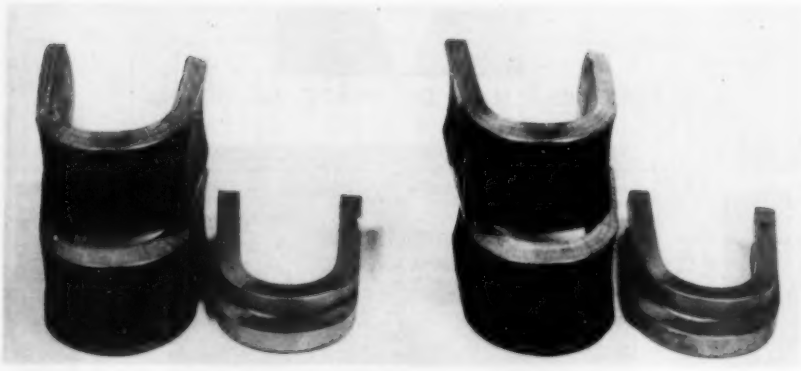


Fig. 15 Inert-arc welding tests—7-in. OD x 5/8-in. thick 2% 1/4Cr – 1% Mo steel pipe. Horizontal fixed position—U welding groove—no preheat. Tests 13 and 14

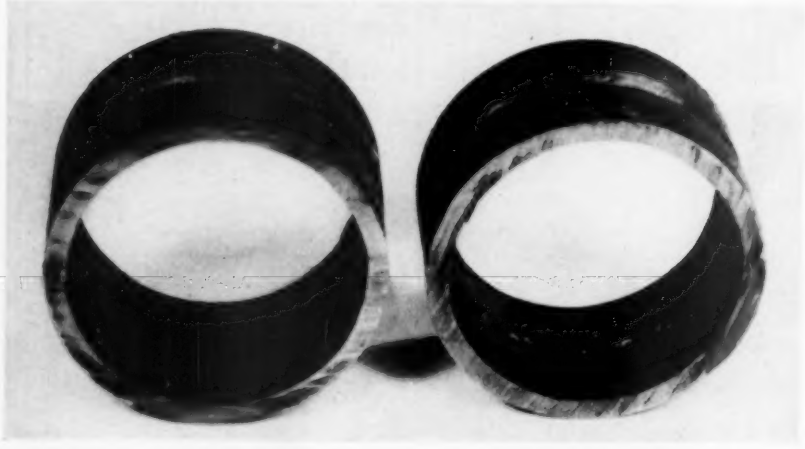


Fig. 16 Inert-arc welding tests—3-in. diam x 7/32-in. thick Grade A carbon steel pipe (inert arc first pass only—weld completed by metal arc). Top half-horizontal fixed position—V welding groove, no preheat. Tests 25 and 26

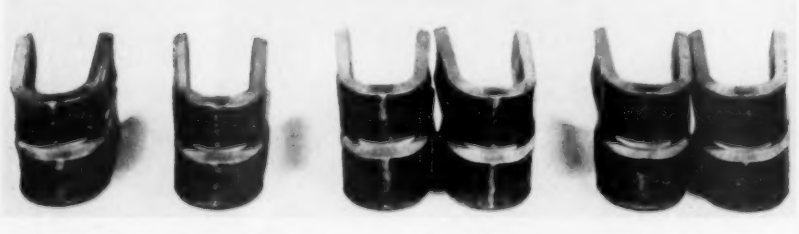


Fig. 17 Inert-arc welding tests—7 in. OD x 5/8-in. thick 2 1/4% Cr – 1% Mo steel pipe (inert arc first pass only—weld completed by metal arc). Tests 1 to 4, incl.

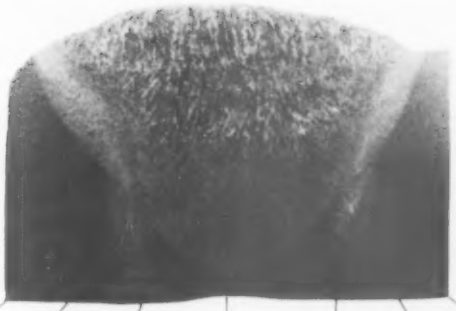
However, studies conducted on Type 347 austenitic steel pipe without purging resulted in root cracking so severe that it was impossible to finish the welds for test.

While inert gas has been successfully employed with suitable fixtures as previously described for purging of pipe assemblies for welding, less expensive gases such as carbon dioxide may be equally effective. In field erection of large assemblies not readily accessible for the use of purging fixtures, "dry ice" placed in the pipe at the weld location may provide adequate gaseous protection. Tests for evaluation of purging gases other than argon or helium are contemplated for future investigation.

To evaluate the need for preheating air-hardening alloy pipe material prior to inert-arc welding the first pass, a series of welds were made in 1/2-in. thick 4 to 6% chrome–1/2% molybdenum steel pipe. The effectiveness of preheating was determined by the hardness and metallurgical structure of the root bead and adjacent parent metal in the as-welded condition. The test conditions and resultant hardness distribution are shown in Fig. 18. The data shows that a 500° F preheat had no effect on hardness. Also, the inert-arc root beads with and without preheat exhibited similar bainitic microstructure. The ineffectiveness of the preheat operation was attributed to insufficient heat retained by the thin lips of the mating pipe ends (machined with the standard U bevel) to slow down the cooling rate of the small inert-arc weld bead. It was noted that due to the annealing effect of the subsequent metal-arc deposition to complete the 5% chrome-molybdenum (for which the joint was preheated to 500° F), the initial hardness of the inert-arc root bead was substantially reduced. Also, tests conducted on 2 1/4% chrome–1% molybdenum pipe indicated no cracking difficulties due to lack of preheat for the inert-arc root bead (Fig. 17). However, the hardened, and less ductile, condition of the as-deposited inert-arc root beads in chrome molybdenum steel pipe assemblies, regardless of preheat, makes it advisable to exercise caution in the handling of such fabrications immediately after inert arc welding, particularly so after tack-welding operations.

Based on laboratory test results, preheating of the chrome-moly alloy steels prior to the deposition of the inert arc first pass appears to be an unnecessary operation. However, it is considered safe and good practice for shop fabrications and field erections to employ preheat for the entire welding operation on air-hardenable or crack-sensitive ferritic alloy steels, especially if there is an external restraining force on the piping members being joined. The practical experience and proved welding procedures with respect to metallurgical factors for conventional metal arc welding should also apply when employing

FIG. 18. HARDNESS DISTRIBUTION INERT-ARC FIRST PASS IN 4-6% Cr, ½% Mo PIPE. WELD TEST NO. 16



WELD	PREHEATED TEMP. °F MINIMUM		STRESS RELIEF °F	HARDNESS VPN - 30 KG.						
	INERT-ARC 1ST PASS	METAL-ARC WELD		PARENT METAL	HEAT AFFECTED ZONE	WELD FUSION ZONE	WELD ℄	WELD FUSION ZONE	HEAT AFFECTED ZONE	PARENT METAL
INERT-ARC FIRST PASS ONLY	NONE	500	NONE	155	368	389	404	415	364	160
	NONE	500	1350	141	210	213	216	213	195	138
	500	500	NONE	157	343	406	413	402	375	157
	500	500	1350	138	208	197	194	197	208	136
INERT-ARC, FIRST PASS, METAL-ARC COMPLETE	NONE	500	NONE	145	236	230	241	241	244	148
	NONE	500	1350	140	210	200	195	200	211	138
	500	500	NONE	146	242	254	254	257	233	149
	500	500	1350	137	216	206	202	200	207	133
METAL-ARC*	500	500	1350	148	148	198	199	202	163	147

*AVERAGE HARDNESS OF METAL-ARC WELD.

CHEMICAL COMPOSITION

MATERIAL	Si	Mn	S	P	C	Cr	Mo
PIPE	0.19	0.39	0.010	0.014	0.16	4.88	0.52
METAL-ARC WELD DEPOSIT	0.14	0.51	0.013	0.012	0.06	5.27	0.51

Fig. 18 Hardness distribution inert-arc first pass in 4–6% Cr – ½% Mo pipe. Weld Test 16

the inert arc welding method to pressure piping.

INSPECTION OF INERT-ARC FIRST PASS

After welding, the most sure and simple method of determining root penetration and fusion is by visual examination from the inside of the pipe. Special provisions must be made, however, when the weld underside is not readily accessible for examination. A small survey hole in the pipe adjacent to the weld, such as commonly used for radiography in field erection of piping, will permit the insertion of an optical device for visual inspection of the weld. Such a device, containing the necessary prisms or mirrors and a suitable light source, should preferably incorporate an indexing system for easy location of defective weld areas with reference to the outside circumference of the weld.

Radiographic inspection of the inert-arc root bead is generally not satisfactory in revealing the possible incomplete fusion that may exist with improper welding technique between the tightly butted pipe lands. A very exacting radiographic technique must be employed in that the sensitive X-rays or gamma-rays should be coincident or within very close proximity of a plane containing the butted pipe lands, and good sensitivity along with extreme care in film processing must be obtained to reveal any incomplete penetration and fusion. However, Fig. 19 shows a suggested method to improve the radiographic interpretation and facilitate the inspection. The bottom portion is machined with a small chamfer which forms a gap that is easily picked up by radiography when incomplete penetration and fusion is present. When complete root fusion is accomplished, the gap disappears and a passable exograph is obtained. Radiography should be performed after completion of the inert-arc first pass, both for greatest definition and to permit easy repair by remelting the unfused portion of the weld.

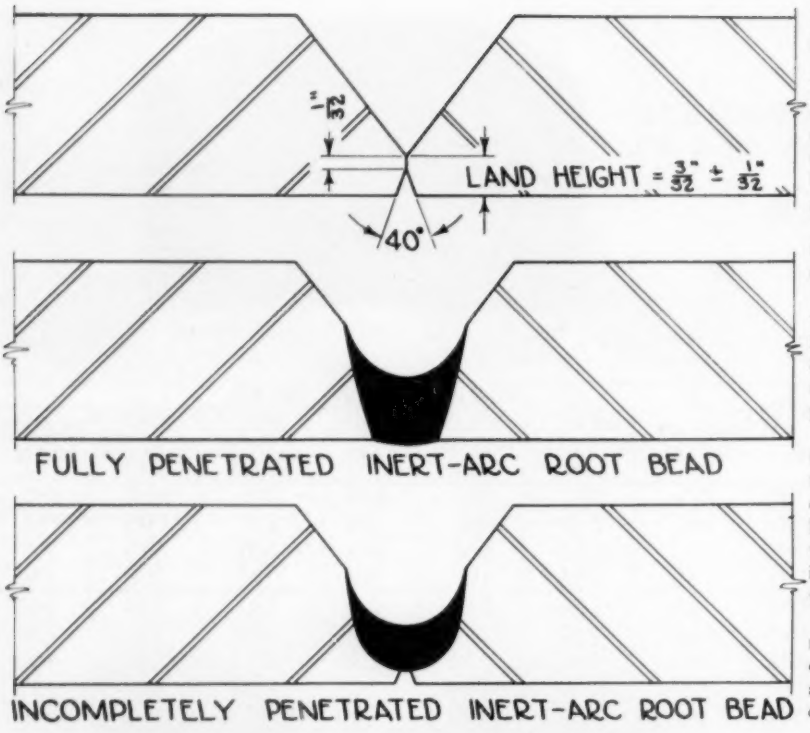
The investigation of the magnetic particle inspection method for determining incomplete root fusion of ferritic piping alloys was not carried far enough to arrive at definite conclusions but the method appears to be promising with further study. There is no doubt that with serious consideration to the problem of inspecting the root condition of inert-arc fused welds, many simple methods can be devised. The major problem lies in the inspection of field erected piping where in many cases the underside of the weld is not readily accessible. Shop fabrication lends itself to superior methods of handling sectional weldments.

SUMMARY

The following concluding points may be made in summary to the development of the inert-arc first pass technique for eliminating backing rings in pressure piping:

1. Fusing the root portion of butted pipe with the inert-arc torch and proper welding technique has produced pipe interiors free of weld drippings and undercut, and presents a very clean, smooth inside surface.

2. The application of the inert-arc technique to pipe materials such as carbon steel, chromium-molybdenum alloy steels and chromium-nickel austenitic steels as



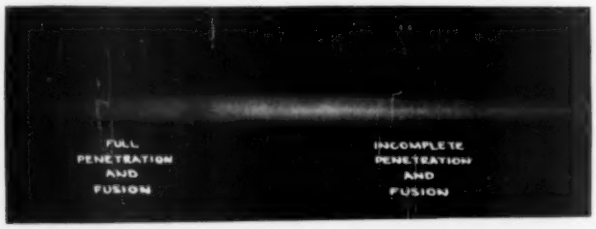


Fig. 19 Radiographic inspection reveals lack of penetration indicated by small groove

covered in this investigation was successfully accomplished and presented no welding difficulties.

3. The satisfactory production of the inert-arc fused root was not dependent upon pipe wall thickness.

4. The present ASA standard 20-deg. U bevel, with a slightly heavier land dimension applied to any pipe wall thickness, was found to be the most suitable for all positions of welding. The use of the standard 37½-deg. V bevel, which is normally applied to pipe wall thickness ¾ in. and less, resulted in a depression at the root of the weld in the overhead position of welding. The V bevel, however, produced satisfactory root appearances for pipe in the horizontal rolled position and in the top half portion of the horizontal fixed position.

5. Properly mated and aligned pipe lands were necessary for the ultimate in smooth appearance of the weld root underside. For best results, the amount of offset between mating welding lands should be held to a minimum, preferably not greater than 1/16-in. total on the diameter.

6. The use of either argon- or helium-shielding gas during inert arc welding produced equally satisfactory results.

7. The use of a protective gas purging to the underside of the welding joint was found to be a necessity for joining Type 347 austenitic stainless steel pipe, and also considered desirable for joining ferritic pipe materials.

8. Preheating for the inert-arc fused root portion of pipe welds was deemed to be a requirement of that specified for conventional metal arc welding, although laboratory tests showed that nonrestrained welds in ferritic materials could satisfactorily pass the prescribed jig root-bend tests without such a treatment.

9. Inspection of the inert-arc fused root should be performed after completion of the first pass both for greatest definition and to permit easy repair by remelting the defective portion of the weld.

10. This investigation, while conclusively showing that metal backing rings can be successfully eliminated by using the inert arc first pass technique, suggests further development work on protective gas purging and inspection methods.

ACKNOWLEDGMENTS

The authors wish to express their gratitude to Edwin Hemzacek and Paul Hjulin of the Crane Co. Welding Engineering Laboratory for making many of the tests described in this investigation, and also to Crane Co. for the permission to present this article.

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Discussion by H. S. Blumberg and Charles Diehl

Messrs. Root and Mueller and their company have contributed to welding fabrication and engineering knowledge by the presentation of this excellent and direct paper. Industry will benefit from the data given here.

We should like to add briefly our experience to that reported by these authors.

In common with other companies, our organization also has been working for a great many years aiming at the fabrication of welded joints without backing rings.

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This has included consideration of grooves of special geometry and special welding procedures as well as nonmetal chills which could be removed mechanically or even chemically. For some considerable time we too have made use of shielding with gases ranging from the combustible fuel gases to hydrogen and then the inert gases such as helium and argon. Results obtained in our laboratories and shops parallel those reported here today.

The authors have given us a valuable 10-point set of conclusions. In the final one they suggest that further development work should be done. We can report such work and believe that we have carried the process forward to achieve results not obtainable heretofore. My comments from here on will deal only generally with this development, since a technical paper is now being prepared which will soon be available for presentation and publication.

In the interest of our company in producing welds which will stand up under extremely severe and demanding service conditions, such as corrosion, contact with radioactive materials, high rates of flow, and high rates of heat transfer with sudden changes at high temperatures, it was felt that welded joints with optimum qualities were necessary. This has resulted in the development of a controlled technique which has now been in production use for a sufficient period of time to have proved the feasibility and practicality of the process. No backing ring is necessary. The method utilizes inert gas welding, specific groove geometry and controlled gas pressure on the inside of the part being joined, as a result of which root beads are produced with internal surfaces of controlled contour. Thus, a flat weld flush with the inside of a pipe can be achieved, or the surface may be made convex to a predictable degree. It is only necessary to use this special technique for the root of the weld; subsequent filling of the groove may be done by more conventional welding methods. There is thus available a controlled procedure for butt welding pipe and other shapes from one side with assurance of complete penetration, control of contour of inside surface of the weld, without the presence of actual cracks, notch effects, excess metal and stress raisers. A typical view of the inside surface is shown.

In the evaluation of the process, welds have been made in tubing and piping materials used by the power plant, oil refinery and chemical plant industries, since such installations have great need of this type of fabrication. Welded joints have been made in the following steels: Plain carbon steel; carbon-molybdenum steel; $^1/_2$ Cr-$^1/_2$% Mo steel; 1% Cr-$^1/_2$% Mo steel; 2$^1/_4$% Cr – 1% Mo steel; 5% Cr – $^1/_2$% Mo steel; 19% Cr – 9% Ni, Cb Grade (AISI Type 347) steel; 19% Cr – 9% Ni, Ti Grade (AISI Type 321) steel.

Weld quality obtained by this process easily meets all X-ray, physical and mechanical requirements of the ASME Boiler Code. Tensile-bend, notched-bar impact and torsion tests have demonstrated excellent properties; these tests, correlated with chemical composition, macroscopic and microscopic examinations, show no tendency for crack formation at the edges of the inside bead. The technique is also applicable to metals other than steel such as nickel, copper, aluminum and their alloys.

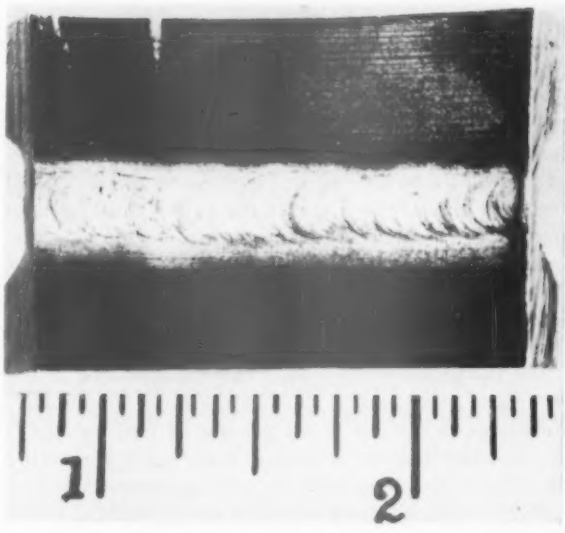

Fig. 1 K weld. View of typical inside surface showing unoxidized weld surface and deoxidized heat-affected zone. CMo steel

Production use of this process thus far has been on a number of shop jobs, including one in which SAE 4130 steel (0.30 C, 1 Cr, 0.15–0.25 Mo) welded shells in relatively thin sections were ultimately heat treated to a tensile strength of 150,000 psi minimum. Most noteworthy was the use of the process in the welding of steam power-plant piping designed to operate at 1100° F normal (1150 max) and 2350 psi normal, (2600 psi max). Here it has been decided to increase steam velocities in order to save strategic materials. The use of the developed welding technique gave beads of optimum contour of the inner surface and has eliminated any concern with respect to turbulence and other disadvantages caused by backing rings, notches and stress raisers. Material used was Type 347 austenitic stainless steel (19–9 Cb) 9$^1/_2$-in. OD x 1$^1/_2$-in. wall. All welds were made under shop conditions; process and welder qualification tests were passed without difficulty. The next stage in the fabrication of this installation requires the completion of welds in the field, which is now in progress.

Authors' Reply

Messrs. Blumberg and Diehl's discussion is greatly appreciated since it contains information that further supports the successful elimination of backing rings in piping when employing the inert-arc welding process.

It is of great interest to learn that other fabricators have also selected and approved the same approach to the problem of improving the root condition of pipe welds. From the discussion, it is assumed that the root pass technique is similar to that described in the paper, except that a *controlled* gas pressure is utilized on the underside of the welding joint. To relate from our experience on similar work conducted in the year 1949 we have found that a controlled pressure of an inert gas (argon) on the underside produces any desirable shape root bead provided the pressure is adjusted for the position of welding. That is to say, welding a pipe fixed in the horizontal position requires a second operator to reduce the pressure when the welder is operating in the overhead position, and the pressure must be gradually increased as the top or flat position of pipe welding is approached in order to produce a uniformly penetrated root condition (assuming the welding generator is at a fixed current setting for the entire circumferential weld). However, when the pipe is rotated and the welding is carried out in the flat or downhand position, a controlled positive pressure produces a uniform shape of the weld underside even with some variations in operator technique. Since 1949, we have found that merely a "purging" operation as described in the paper coupled with the experience of a welding operator with just a relatively short period of training will produce a satisfactory result which is more practical for both shop and field welding of piping.

Messrs. Blumberg and Diehl cite successful shop experience with AISI Type 347 piping which is of great interest to us. This particular piping alloy, at the time our paper was presented, was studied only from an experimental viewpoint and showed no welding difficulties. However, shop application since that time to Type 347 assemblies that were, metallurgically speaking, entirely austenitic, showed evidence of weld cracking. In order to take this opportunity to bring the paper up to date, it might be stated that this difficulty can be alleviated by "buttering" the pipe ends prior to machining the welding bevel with metal-arc deposits of "ferrite-containing" Type 347 weld metal. The root portions of butted pipe containing fused lands of approximately 5 to 8 per cent ferrite showed no cracking difficulties. This again, only emphasizes the statement in the paper that "the practical experience and proved welding procedures with respect to metallurgical factors for conventional metal-arc welding should also apply when employing the inert-arc welding method to pressure piping."

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(*Continued on page 229*)

Resistance Welding of Dissimilar Metals to Magnesium for Electrical Connections

Conditions for direct welding of copper and other wires to magnesium and indirect methods of interposing zinc or coated steel strips

by Paul Klain and H. W. Croisant

Abstract

This paper describes a method of resistance welding for attaching wires to magnesium dry batteries and to other magnesium parts where electrical contact is necessary, such as in electronic applications for grounding purposes. The conditions for direct welding of copper and other wires to magnesium are described. An alternative method of first spot welding strips of zinc or coated steel sheet followed by soldering of wires to these strips for electrical contact is also described.

INTRODUCTION

THE increasing uses of magnesium in parts and assemblies requiring good electrical contact for grounding or current conduction purposes has focused attention on the development of rapid and economical methods of attaching wires for those purposes. The rapid development of the primary dry cell batteries using magnesium as the anode has greatly intensified the need of a sound and rapid method of attaching wire leads. Therefore an investigation was initiated to develop techniques of attaching lead wires to magnesium not only for the primary battery uses but also for grounding of assemblies in electrical and electronic applications of magnesium.

Magnesium dry cells have shown considerable promise in certain applications because of their high capacity discharge characteristics. Theoretical data[1] indicate that 1 lb of magnesium would deliver 2.7 times as many ampere-hours of current at three times the anode voltage as would 1 lb of zinc. Practically, however, the difference is not as striking, but is still appreciable. It has been established[2] that the number of magnesium cells required in the series batteries was 15 to 20% less than the number of zinc cells for a desired voltage. This advantage becomes especially significant in pack batteries as well as other applications from the standpoint of possibilities of weight saving and reduction in size.

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A consideration of the requirements of intercell connections indicates that the joints must withstand 95% relative humidity at 90°F for 500 hr. The joints also must have good electrical contact and conductivity. Joint strength is not important and it is only necessary to have sufficient strength and flexibility for handling during assembly. The material for electrical connections is universally copper wire. However, it is a well-known fact that copper forms brittle compounds when alloyed with magnesium, and that contact corrosion under certain conditions can be severe.

With these limitations in mind, soldering and resistance welding were examined. Initially, most effort was directed to developing soldering techniques. A fluxless soldering method using 50 Sn – 50 Pb solder was finally developed, but because of corrosion and other problems, attention was directed to resistance welding. The latter offered such promise that the soldering method was abandoned in favor of resistance welding. It is the purpose of this paper, therefore, to describe the conditions under which successful electrical connections can be made to magnesium and to point out the present application of this process in the magnesium batteries.

MATERIALS

Resistance welding tests were carried out chiefly on AZ31A (Mg – 3Al – 1Zn – 0.2Mn) alloy in the form of sheet and as impact-extruded battery cans with wall thicknesses of 0.022 to 0.075 in. Alloy AZ10A (Mg – 1Al – 0.5Zn) was also used in dry batteries and was welded satisfactorily. Either mechanically (wire brushed) or chemically prepared surfaces were satisfactory for welding. The chemically cleaned surfaces were used in all tests since the chemical treatment[3, 4] is a part of the normal processing of the battery cans after impact extrusion.

Most of the materials welded to the magnesium were in the form of wire although a few tests were also made with flat pieces. The greater share of the tests was made with soft drawn bare and tin coated copper wire

of No. 22 AWG. Other sizes investigated were No. 30, 28, 26, 20 and 18 AWG and the Belden "Derrick" wire made up of 7 strands of No. 32 gage tin-coated copper wire with an over-all size of No. 24 AWG. The stranded wire has proved most successful for intercell connections because of its flexibility. Other wire materials welded to magnesium were 0.028 in. pure magnesium and AZ61A alloy (Mg – 6Al – 1Zn – 0.2Mn), 0.045 in. nickel, 0.045 in. stainless, 0.0375 in. Alumel, No. 22 AWG Constantan and No. 20 iron wire coated with tin, zinc, cadmium and 50/50 Sn-Pb solder. Spot welding of flat copper and zinc as well as galvanized and tin-coated steel sheet was also tried. All the materials were clean and were used in the as-received condition.

EQUIPMENT

A bench-press type of welding machine, rated at 5 kva, 440 v, single phase, 60 cycle a.c. and equipped with an air cylinder for raising and lowering the upper electrode, was used. The conventional platens were removed and a spring-loaded tip holder and a bottom plate were added. The control equipment consisted of a Thyratron 1–10 cycle current timer and phase shift heat control. A NEMA type 3B sequence timer was also added. The complete equipment is illustrated in Fig. 1.

In operation, the upper electrode was raised and lowered by the air cylinder, which in turn was governed by electronic controls. The electrode force was applied by the adjustable spring through the hexagonal

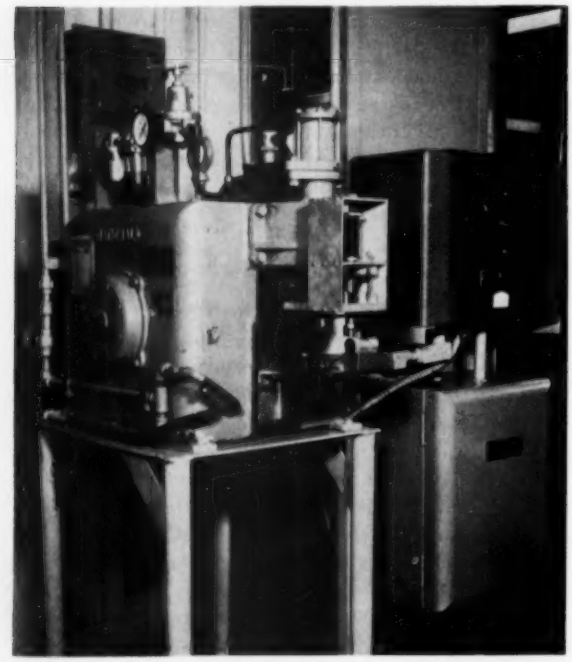

Fig. 1 Resistance welding equipment for welding wires to magnesium

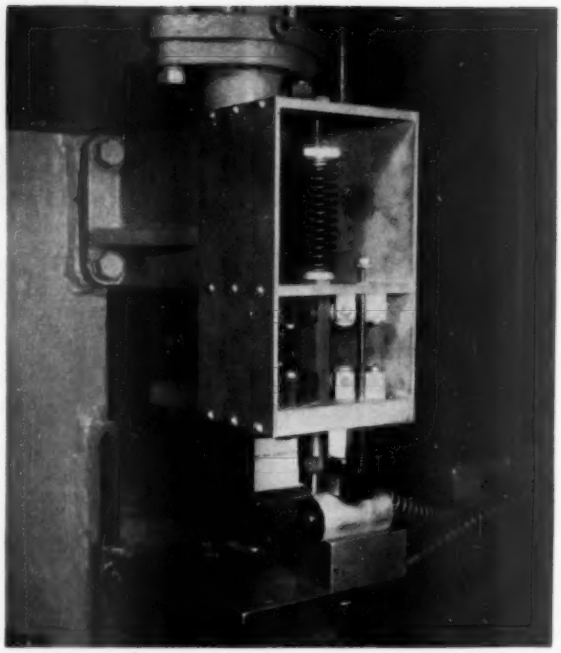

Fig. 2 Spring-loaded upper electrode assembly

guide rod, which was guided by six sets of ball bearings to give low inertia rapid follow-up (see Fig. 2). This arrangement allowed electrode forces up to 36 lb to be applied when welding. The lower electrode shape was varied depending on the type of work to be welded. For wire to sheet welds, a $^1/_2$-in. diam copper electrode was fixed to the bottom plate. For the round battery cans, a 120-deg V-grooved copper block was used as shown in Fig. 2. In addition, a spring-loaded hold-down block was necessary to obtain a good contact and to prevent tipping of the cells in the cradle.

The upper electrode assembly used a $^1/_4$-in. diam air-cooled copper electrode tapered to a $^3/_{16}$ diam at its tip. Rapid fouling and grooving of this electrode occurred. By silver soldering a molybdenum disk $^1/_8$ in. thick to the tip, a remarkable improvement resulted. Recent reports from several battery manufacturers indicated up to 5000 welds were possible before tip cleaning was necessary. The molybdenum disk must not exceed $^1/_8$ in. thickness since the high resistance of molybdenum would result in overheating and poor tip life. The shape of the tip could be either flat or domed, the latter giving less fragile joints.

PROCEDURE

The positioning of the wire and the electrode with respect to the edge of the sheet or the battery can was kept as constant as possible. The upper tip was allowed to overhang the edge of the sheet or battery can by $^1/_{32}$ in. to prevent squashing and weakening of the wire. The length of the wire welded was held constant by lapping the wire over the sheet a distance equal to the diameter of the tip. The currents for each weld were obtained

by using a pointer stop ammeter in the primary and converting these values to secondary current by calculation from a knowledge of the transformer turn ratios. The current values obtained in this manner were known to be somewhat inexact, but the method was used because the values provided some measure of relative evaluation of machine settings which otherwise would have been of little value.

The wire welds were evaluated by tension testing and by "peel" testing. The latter consisted of pulling on the wire at 90 deg to the weld. The tension test did not evaluate the bond because the overlap and the resulting area of the wire bond was stronger than the wire and failures occurred in the wire. However, a combination of the tension and the peel test served as an adequate method of evaluation for the purpose of cell attachment.

RESULTS

Electrode Force

The results of tests of varying the electrode force are summarized in Table 1. The tests were conducted on 0.040-in. AZ31A alloy sheet, using No. 22 AWG bare copper wire and electrode forces of 8, 12, 16, 20, 24, 30 and 36 lb. The data showed a wide current range for any electrode force and considerable overlapping of current values for the various forces, while the tensile weld strengths remained almost unchanged.

Table 1—Effect of Variation of Electrode Force on Bare Copper Wire Welds. Tests on 0.040-In. AZ31A Sheet and No. 22 AWG Bare Copper Wire

Electrode force, lb	*Secondary current, amp*	*Tensile breaking load, lb*	*Peel test load, lb*	*% set down (penetration) of wire*
8	1330–2300	8.8–16.1	2.9	20– 80
12	2420–3110	15.4–16.1		60–100
16	2440–3890	15.4–16.1	4.8	60– 85
20	2180–4170	15.6–16.4	4.9	50–100
24	2380–4380	16.1–16.6	4.8	50–100
30	3160–4500	16.5–17.2		50–100
36	3280–4700	16.4–17.0		90–100

The set down or penetration of the wire into the sheet could be varied from 50 to 100% (based on original wire diameter) without having any visible effect on weld strength. Perhaps the most significant and also the most favorable conclusions that could be drawn from the data were that the welding conditions were not critical and a wide range of machine settings could be used to obtain satisfactory welds. For the most consistent welds, a minimum force of 12 lb and a minimum set down or penetration of the wire of 50% were required.

Weld Time

The results of weld current times are given in Table 2. Satisfactory welds were obtained at times of 1 to 8 cycles. Considerable arcing occurred at 1 and 2 cycles resulting in rapid tip fouling. Indications were that short timing cycles resulted in narrower and more critical welding conditions. Therefore, all subsequent welding was performed at 3 to 6 cycle weld current times.

Table 2—Variation of Weld Time for Welds of No. 22 AWG Bare Copper Wire to 0.040-In. AZ31A Sheet Made at 20 Lb Electrode Force

Weld time, cycles	*Secondary current, amp*	*Tensile* breaking load, lb*
1	2070	17.7
1	2670	...
1	3020	18.3
2	2530	18.8
2	3400	17.9
2	3640	18.3
4	2970	18.5
4	3860	18.7
6	2160	18.7
6	2420	18.4
6	3860	18.3
6	4260	18.0
6	4400	18.4
8	3740	18.8
8	4110	17.4
8	4400	18.8

* Average of 5 tests.

Magnesium Stock Thickness

The range of welding currents for magnesium sheet thicknesses of 0.020 to 0.064 in. is listed in Table 3. Again, a very wide range of currents was available for each thickness together with some overlapping in values. Welding current increased to some extent with increase in sheet thickness but there was nothing critical about the increase.

Table 3—Typical Range of Welding Currents for Various Thicknesses of AZ31A Sheet and No. 22 AWG Bare Copper Wire. Tests at 20 Lb Force and 6 Cycle Welding Time

Sheet thickness, in.	*Secondary current, amp*	*Tensile* breaking load, lb*	*Peel test* load, lb*
0.020	2550	16.2	3.6
0.020	4880	16.5	4.9
0.032	2970	16.7	...
0.032	4880	16.9	4.4
0.040	2890	15.6	...
0.040	4170	16.4	...
0.064	2950	16.8	2.6
0.064	>5000	16.2	4.3

* Average of 5 tests.

Bare Copper Wire Size

The results of welding bare copper wires of AWG Nos. 30, 28, 26, 22, 20 and 18 to 0.040-in. AZ31A sheet at a constant force of 20 lb are given in Table 4. Again widespread ranges of overlapping current values were obtained. In general, the current required to make the welds increased with increasing wire size but the spread was such as to preclude the establishment of definite

Table 4—Results of Welding Different Gages of Bare Copper Wire to 0.040-In. AZ31A Sheet at a Constant Electrode Force of 20 Lb and Weld Time of 6 Cycles

*Wire size AWG No.**	*Secondary current, amp*	*Tensile† breaking load, lb*	*Peel test† load, lb*
30	1810–4260	3.0–3.6	0.7
28	2100–4320	5.0–5.3	..
26	2530–4400	6.9–7.6	..
22	2180–4170	15.6–16.4	4.8
20	3110–4370	29.4–30.1	7.9
18	2970–4030	41.9–44.0	12.1

* AWG—American Wire Gauge (Brown & Sharpe).
† Average of 5 tests.

increments for the sizes. The strengths of the welds increased with the size of wire since failure in all cases was by fracture in the wire itself at some distance away from the weld. The penetration of the wires into the sheet was close to 100%. The results showed that single-strand bare copper wire in sizes from No. 30 to No. 18 could be satisfactorily welded to magnesium.

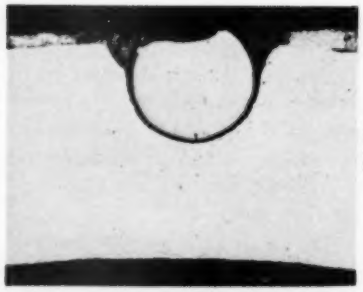

Fig. 3 (*a*)
Etchant: Glycol
Wire: Solid
Size: No. 26 AWG
Coating: Sn. × 50

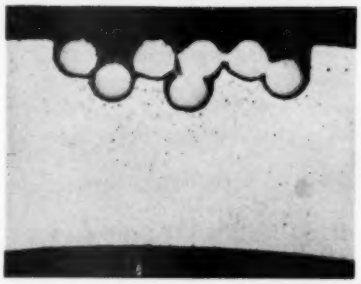

Fig. 3 (*b*)
Etchant: Glycol
Wire: 7 Stranded (Belden "Derrick")
Size: No. 24 AWG
Coating: Sn. × 50

Fig. 3 Copper side wire welded to magnesium battery cans

Battery can: AZ31A, 0.023-in. wall, "N" size. Welder: a-c transformer, synchronous current control.

Coated Copper Wires

For most electrical applications where wire joints are soldered to obtain good electrical contact, a tin coated wire is normally used. Since the wire connections in batteries required the best joints possible and the tinned wire was normally used for this purpose, a series of welding tests was made with bare, tin, zinc, cadmium and solder (50 Sn – 50 Pb) coated wires. The zinc and solder coats were put on by dipping bare copper wire in the molten metals, while cadmium was put on by electroplating. The "tin-coat" was that present on the wire when obtained from outside sources.

Welding tests showed that cadmium coated wires were difficult to weld because of arcing and vaporization of the cadmium. The other coatings resulted in welds that were equally as good as the bare wire. There was an indication that the tin, zinc and solder coated wires resulted in more consistent welds than the bare copper. The zinc coating had the disadvantage that it made the wire stiffer and more brittle. Therefore, since the tin coated wire was a commercial article, additional welding tests were made comparing the single and the multiple strand types. The results in Table 5 showed no unusual differences in welding current, although there appeared to be a tendency for higher current in the case of the multiple strand wire. The somewhat higher strength of the single-strand tin coated wire was due to higher strength of the original wire.

Table 5—Welding Conditions for Tinned Single- and Multiple-Strand Copper Wires. Tests at 20 Lb Electrode Force and 6-Cycle Welding Time on 0.040-In. AZ31A Sheet

Type of copper wire	*Coating*	*Size AWG No.*	*Secondary current, amp*	*Tensile* breaking load, lb*	*Peel test load, lb*
Single strand	Bare	22	2180	16.4	
			2370	16.2	
			3110	15.9	
			3890	15.6	
			4170	16.4	
Single strand	Tin	22	2160	18.7	
			2420	18.4	
			3860	18.3	
			4260	18.0	
			4400	18.4	
Multiple strand	Tin	24	2920	11.1	3.1
			3200	11.2	2.9
			4400	12.5	2.6
			4770	11.9	2.5

* Average of 5 tests.
† Belden "Derrick" Wire—7 strands of No. 32 AWG.

The appearance of the single- and multiple-strand tin coated copper wire welds is shown in Fig. 3. The molten magnesium and the eutectic or compounds were squeezed out to the surface of the magnesium sheet. In the multiple-strand wire, the voids between and on the top of the wires were filled and some of the wires fused together. This condition should make for stronger bonds. Higher magnification of bare and coated copper wire welds in Fig. 4 showed that the bonds were metallic and that narrow zones of eutectic were formed. The metallurgical structure of the bond was influenced and appeared to be dependent on the surface coating. The microscopic examination established definitely that copper to magnesium welds were truly metallurgical in nature. However, the weld strengths were a result of both metallic and mechanical bonding, which was clearly evident from the penetration of the wires into the magnesium. In general, the bonds were brittle in nature as might be expected from the knowledge that copper and magnesium form brittle compounds. Most of the joints were

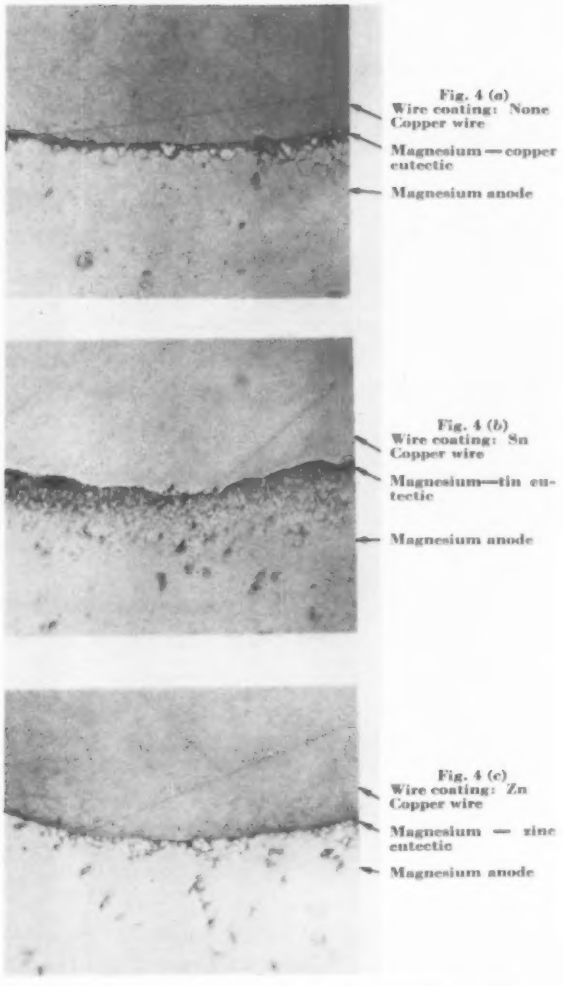

Fig. 4 Eutectics of magnesium formed by welding

Battery can: AZ31A 0.023-in. wall, "N" size. Welder: a-c transformer, synchronous current control. Etchant: Glycol. Wire: Solid copper × 400.

sufficiently strong to withstand the bending of the wires as required during assembly of the cells, although occasionally some single-strand wires broke off. For that reason, multiple strand wires have been recommended and have been in use for intercell connections.

Miscellaneous Wire Welds

The results of welding wires other than copper are summarized in Table 6. Magnesium alloy AZ61A and pure magnesium wires of 0.028 in. diam were difficult to weld because of their softness. Even at the lowest electrode force tried (8 lb), both wires flattened as much as at higher forces. The AZ61A alloy was so embrittled that no tests were possible. The pure magnesium wire gave values of 8 to 11 lb and failed at its constriction.

Since no alloy formation and therefore no metallurgical bond was possible with iron, the wires were dip

Table 6—Results of Welding Miscellaneous Wires to 0.064-In. AZ31A Sheet at 20 Lb Electrode Force and 6-Cycle Welding Time

Type of wire	*Diameter in inches*	*Coating*	*Secondary current, amp*	*Tensile* breaking load, lb*	*Peel test* load, lb*
Magnesium	0.028	None	2820	11.3	...
			3250	8.0	...
			3680	11.2	...
			4030	10.0	...
Iron	0.032	Tin	4400	56.0	3.6
		Tin	5600	53.8	6.3
		Zinc	3400	56.2	4.4
		Zinc	4320	54.2	5.6
		Solder	4320	52.5	2.9
		Solder	4320	50.5	4.8
Nickel	0.045	None	4550	55.5	...
Stainless	0.045	None	4320	26.4	...
			4700	34.5	...
Constanton†	0.032	None	3670	35.6	...
Alumel‡	0.038	None	4750	62.8	...

* Average of 5 tests.
† Constanton—Nominal composition 60 Cu – 40 Ni.
‡ Alumel—Nominal composition 94Ni-2Al-3Mn-1Si.

coated with tin, zinc, and 50 Sn – 50 Pb solder. The results of welding these coated wires are also given in Table 6. The strengths were fairly uniform ranging between 50 and 56 lb. Failures occurred both through the weld and in the wire itself. Intermetallic bonds were observed to be present in weld fractures. Cross sections showed the presence of eutectics of tin and of zinc in the magnesium side of the welds and also the squeezed-out eutectics of these two metals (Fig. 5) as in the case of the coated copper wire welds. Some surface melting and therefore flattening of the iron wires occurred as shown in the cross sections. The results of these tests showed that iron wires coated with tin, zinc or solder gave satisfactory metallic bonds

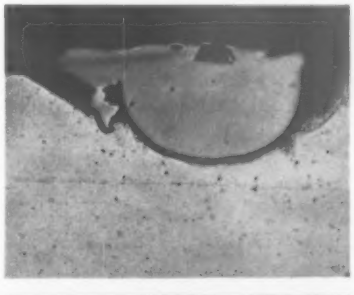

Fig. 5 (a) Glycol etchant Zinc-dipped iron wire to 0.022-in. wall cell can. × 50

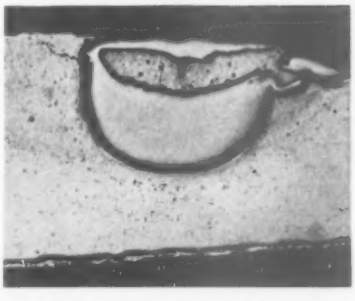

Fig. 5 (b) Tin-dipped iron wire to 0.022-in. wall cell can. × 50

Fig. 5 Cross sections of tin- and zinc-coated iron wire welds to AZ31A alloy

with magnesium by resistance welding and could be used in applications requiring metallic contact. Cadmium coated wires were not satisfactory because of arcing and vaporization of cadmium.

Nickel, Stainless Steel and Other Wires. Stainless steel wire to magnesium welds were attempted because of the high nickel content, which could conceivably result in metallic bonding because of the alloying ability between nickel and magnesium. However, the results indicated only mechanical bonding was obtained. Nickel wire on the other hand, showed evidence of metallic bonding, which was further confirmed by strengths of 55.5 lb for nickel and only 34.5 lb for stainless as shown in Table 6. In both cases the tensile failures occurred through the weld by pulling away of the wires. Two other wires, Constantan and Alumel, which were copper and nickel base, respectively, also showed evidence of good metallic bonds.

Flat Stock

The copper wire welds were satisfactory for the battery application, but the brittle nature of the bond might make them unsatisfactory in other applications where some degree of continuous handling or vibration was encountered. Therefore an alternative method which would give less brittle bonds was sought. The approach to this problem was to spot weld strips of metal to which the conventional soldering technique could be applied. A series of spot welding tests was performed using a rocker arm a-c machine. The tests included the welding of 0.031-in. galvanized, 0.028-in. tin coated steel and 0.031-in. zinc sheets to 0.040-in. AZ31A sheet. Very satisfactory welds were obtained. Tension tests resulted in the tearing of slugs out of the magnesium sheet. Some surface burning of the coated steel sheet was obtained when making the welds. To obtain an idea of the performance of these spot welds, the galvanized sheet to magnesium welds were exposed for 28 and 60 days to 95% relative humidity at 90°F and then pulled in tension. The strengths did not appear to be affected by the humidity as is shown by the values in Table 7. Both the exposed and the unexposed specimens tested at 300 to 400 lb per spot. The fractured specimens are shown in Fig. 6. Practically no corrosion occurred at the interface of the 28-day specimens but appreciable corrosion occurred on the 60-day specimens although the weld strengths were not affected. Zinc strip was also successfully

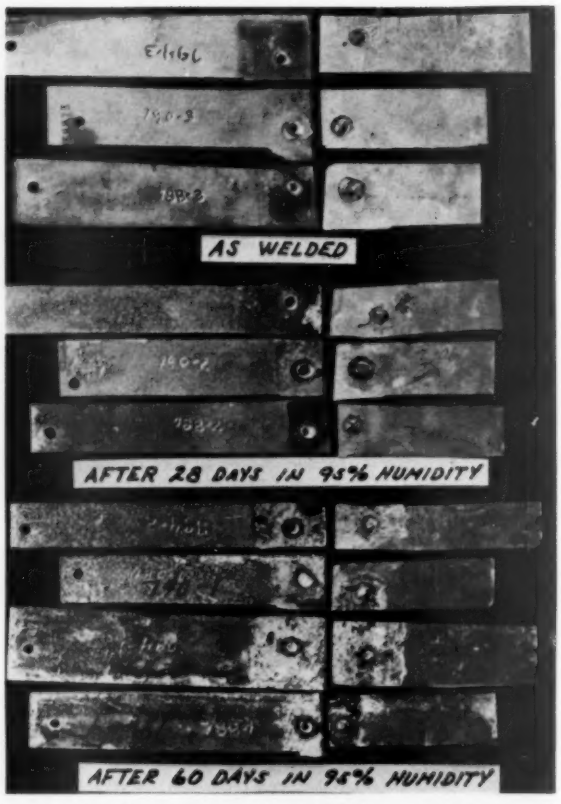

Fig. 6 Fractured spot welds of 0.040 in. FS1O to No. 22 gage galvanized sheet

spot welded to magnesium but bare copper was not. The results of these tests have shown that electrical connections could be made to magnesium by first spot welding pieces of zinc, galvanized sheet or tin coated steel sheet and soldering the lead wires to these strips by conventional techniques. In this way substantially stronger joints could be obtained than by direct resistance welding of wires of dissimilar metals to magnesium.

Table 7—Spot Strengths of Galvanized Steel (No. 26) to Magnesium Sheet (0.040-In.) After Exposure to 95% Humidity

Specimen No.	*Shear strengths, lb*		
	As-welded	*28 days*	*60 days*
1	300	330	337
2	...	376	428
3	292	...	370
4	319	414	405

Application to Magnesium Dry Batteries

The application of resistance welding for attaching wire leads to the primary dry battery magnesium anodes of cylindrical shape will be briefly described. The main dry cell cans vary from $^{7}/_{16}$ to $1^{1}/_{4}$ in. diam and from 1 to 6 in. in height as shown in Fig. 7 with wall thicknesses from 0.022 to 0.075 in. The wires are attached most often lengthwise at the top edge of the battery can on each completed dry cell. The free ends are soldered to the center brass terminal cap as shown in Fig. 8. In this type of battery, a contact spring of hard drawn brass wire is also attached by resistance welding as shown at the extreme left of Fig. 8. It may be noted that the lead wires are multiple strand twists. The stranded type of wire for pack batteries is recommended because of greater flexibility and less

Table 8—Typical Welding Conditions for Battery Cans of Various Wall Thicknesses with No. 24 AWG Tin Coated Stranded Wire[a]

Cell			Welding condition		
Size	*Wall thickness, in.*	*Alloy*	*Time, cycles*	*Secondary current, amp*	*Electrode force, lb*
N	0.023	AZ31A	1	1886	15
AA	0.040	AZ31Z	4	3080	15
AA	0.040	AZ10A	4	2816	15
D	0.050	AZ31A	6	2992	15
D	0.075	AZ31A	8	3168	15

[a] Belden "Derrick" Wire—7 strands of No. 32 AWG.

Fig. 8 Magnesium pack battery with hard-drawn brass wire spring and stranded copper wire leads attached by resistance welding

Fig. 7 Resistance-welded copper wire leads to various sized magnesium dry cells

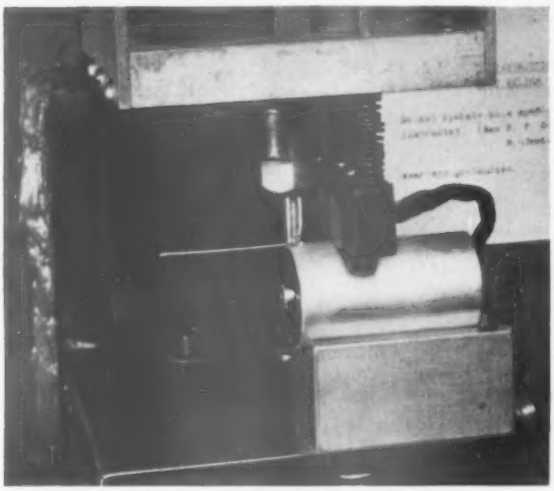

Fig. 9 Positioning of an assembled dry cell for resistance welding of lead wire

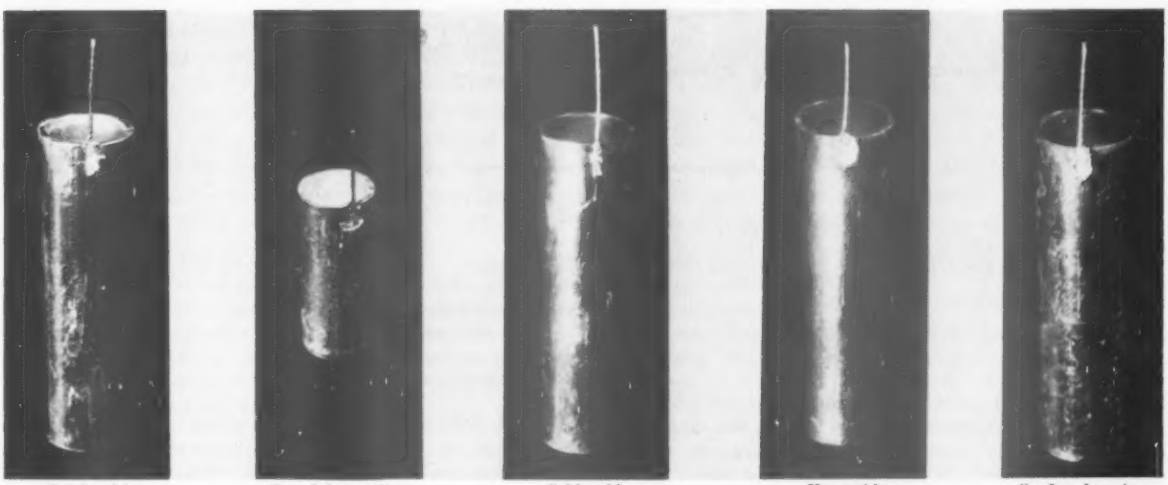

Fig. 10 Typical welds encountered when welding side wires to magnesium anodes

Fig. 11 Assembly of a typical magnesium pack battery with resistance-welded wire leads

strain on the weld. Some typical welding conditions used in various sized battery cans are given in Table 8.

Special techniques for welding wires to round cells were evolved and are now in use. One method for welding wires lengthwise of the can is illustrated in Fig. 9. The filled cell is positioned so that it overhangs the 120-deg V-cradle block by $^1/_8$ in. to keep the sealing wax away from the contacting surfaces. Also, the welding tip overhangs the cell by about $^1/_{32}$ in. to avoid thinning or shearing the wire at the edge of the tip. The wire itself is placed on the can so that it does not project more than $^1/_{64}$ in. beyond the tip. The hold-down bar exerts about 40 lb force and is made conducting for better contact.

The appearance of typical welds illustrating good and poor practice is shown in Fig. 10.

The assembly of a typical pack battery using the small sized cells is shown in Fig. 11. This battery can, with its 0.022-in. wall, gives the most difficulty in welding wires because low electrode forces are required to hold deformation to a minimum. A maximum of 15 lb electrode force was established for this can. The necessity of making close to 90 joints per pack gives some idea of the problem faced by battery manufacturers when the magnesium cell was first developed.

SUMMARY

It has been shown that two methods of attaching wire leads to magnesium may be used. The direct welding of copper wire was satisfactory for batteries where strength of joints was unimportant. However, for other applications where stressing or handling may be encountered, an alternative method, consisting of first spot welding strips of metal, such as zinc or steel coated with tin or zinc, and then conventionally soldering the lead wires to the strips, should be used.

Welding conditions for any given wire size or shape and magnesium thickness were not critical.

For best results, the following wire welding conditions should be used:

1. A minimum electrode force of 12 lb.
2. A minimum penetration or set down of 50%.
3. An upper tip faced with a maximum of $^1/_8$-in. thick molybdenum disk.
4. Welding times of 3 to 6 cycles.
5. Mechanically or chemically cleaned magnesium sheet.[4]

The wire welds showed good corrosion resistance in 95% relative humidity. Exposure times far in excess of the 500-hr test showed no weakening of the bonds.

Iron wires or sheet coated with tin, zinc or the 50 Sn – 50 Pb solder could be readily welded to magnesium for metallic contact.

ACKNOWLEDGMENT

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Houston Exposition and Meeting

A four-day, all-welding exposition sponsored by the AMERICAN WELDING SOCIETY will be held June 16–19, 1953, at The Shamrock Hotel, Houston, Tex., in conjunction with the SOCIETY'S Spring Technical Meeting. This exposition will give an opportunity to the South and Southwest to see demonstrations of the latest technical developments in the field of welding, cutting and its many allied processes.

Most of the major companies of the welding industry will exhibit and demonstrate the welding equipment and processes—over 40 of these companies have already reserved space in the Shamrock's Hall of Exhibits.

The exhibits will be comprised of manufacturers who sell products for welded fabrication, weldments, welding processing, gas cutting, brazing, finishing, tooling, gaging, testing, stress relieving, X-raying, servicing positioning and materials handling.

Houston was selected for this all-welding exhibit because it is the center of the South and the Southwest's welding interests, its ideal proximity to the greatest number of persons in that area who are actively engaged and interested in welding and its allied phases of operation. Those attending will be top executives, engineers, metallurgists, production men, fabricators, process plant men, steelmakers and the welding profession itself.

Unity in Welded Steel Construction

The full potentialities and advantages of welding as a construction tool, the problems encountered during fabrication and the practical methods to control distortion are presented and discussed

by Robert S. Hale

WELDING is a "tool" for the uniting or joining of metals by means of heat. Sometimes pressure and/or a filler metal is used depending on the process employed. Principal welding processes are:

1. Electric arc welding.
2. Gas welding.
3. Resistance welding.

Each has a variety of proper uses and applications. Welding is not a cure all.

Welding might be termed modern blacksmithing, the ancient and presently used method of working metals. The welding processes as we know them today have been developed in this country during the last 50 years. One might say the period of development to a full recognized industry status extended from 1905 to 1945. World War II made the welding industry. Welding use materially aided our country in bringing this catastrophy to so early a successful conclusion, perhaps saving countless lives.

Why can this statement be made? Simply the fact that just prior to Pearl Harbor it was estimated the number of welders in this country approximated 200,000. In 1945 an estimated 1,000,000 welders, both men and women alike, were working in our factories, shipyards and military installations. What did this fivefold increase in man-hours work plus overtime accomplish? Just this—the assembly of multitudinous metal pieces into subassemblies and these subassemblies into a final useful war machine—each produced in large quantities, namely: tanks, ships of all types, trucks, guns, airplanes, etc., too numerous to mention.

No other method used to join metals prior to this time could have produced such quantities of metal war material in so short a period with so few man-hours effort as welding. Naturally older methods were employed and much help was given to the war effort by other processes, but welding came into its own, public confidence was created, even conservative-thinking members of the engineering professions, many who before were skeptical, were convinced of the real value of welding as a metal-joining process.

True, there were a few failures, some hulls of ships cracked, etc., and any failure was given wide publicity by the press, but considering the millions upon millions of tons of metal products produced, both small and large in size, in most all forms, and considering the little experience of about four-fifths of the welder workmen and women, considering the speed into which our production skyrocketed and considering perhaps last, but far from least important, the design of products produced, these few publicity-given failures were infinitesimal. We constantly read or hear of automobile, railroad and airplane accidents; in fact, our newspapers constantly carry this type of news, it helps sell papers. These accidents are caused by failures beyond the control of the one at the controls; sometimes it is a personal or human element failure but many times it is something within the machine that just does not function correctly. We take the news of accidents in our stride every day so when a relatively new process or product receives publicity we should not become excited and condemn the product or process until all the facts are known and then their importance compared with that which we accept daily as the usual news.

Yes, design—yes that most important of all component efforts going into a welded job today—since welders are now better trained and tested, welds are inspected better and tested, shop or field supervision is better trained, welding supplies and equipment are improved—those items are standardized or approaching maturity at least, and naturally constant improvement is the order of the day for them. We will return to the subject of design later.

Now let us approach welding and particularly that portion of the welding field called "welded steel construction," from a more detailed view, considering:

I. Important facts to consider.
II. Some advantages of welded structures.
III. Problems encountered.
IV. The Engineer and the professional approach to welding.

Robert S. Hale, Consulting Engineer, Architect.

This paper is based on a talk delivered by the author before the Chicago Chapter, American Association of Engineers, Dec. 19, 1952.

I. IMPORTANT FACTS TO CONSIDER

1. Welding is an art and must be considered and handled as a profession when done manually by a welder. Automatic equipment can be set for satisfactory results. If considered in this manner the success of structural welding on steel work is equal with the success of the professions of engineering or architecture which have endured through the ages.

2. Welds can be tested by sight inspection with an equal degree of reliability as rivet ringing by one experienced in his work.

3. Design of welded joints for structural steel work has only been partially standardized. Each problem is treated individually. The Engineer is given wide latitude to use his ability. Usually a direct substitution of welds for rivets make a poor welded design. Usually the more welding that is used for a given connection by inexperienced designers than that required for right design in right locations weakens the connection instead of strengthening it—increases costs per unit of product and creates excessive internal stresses which tend to distort members.

4. For any new process or product to grow in importance and be recognized by industries it effects or the general public, it should be an improvement in one or more ways in comparison with the then existing processes or products. These improvements can be expressed in terms of cost, utility, beauty, etc. Allow us then to list and illustrate in more or less detail and by naming examples some of the advantages claimed for welded steel structures, referring particularly to structural steel applications.

II. SOME ADVANTAGES CLAIMED FOR WELDED STEEL STRUCTURES

1. Less weight in a structure: In general, a saving in the weight of 3 to 30% of a good conventional design can be made when a good welded design is adopted on a given job. The exact percentage depends upon many factors, such as the type of building, bridge or structure, its general shape, and the dead and live loads imposed upon it. Each structure therefore requires an analysis throughout its design of main members, connections, etc., to determine where these savings are possible. For example:

Trusses represent an opportunity for the use of certain rolled shapes not used before in truss work such as the heavy T section made by splitting in half the web of I or H beams. Gusset plates many times can be eliminated entirely or reduced in size. Tension members in trusses can usually be made of lighter weight sections because holes which reduce the net area of sections are eliminated.

Columns can show some saving in unit weight by less detail steel for bases, beam brackets, splices, etc. (see Fig. 1). Columns can be designed more readily as one end or both ends are fixed, thus changing conventional

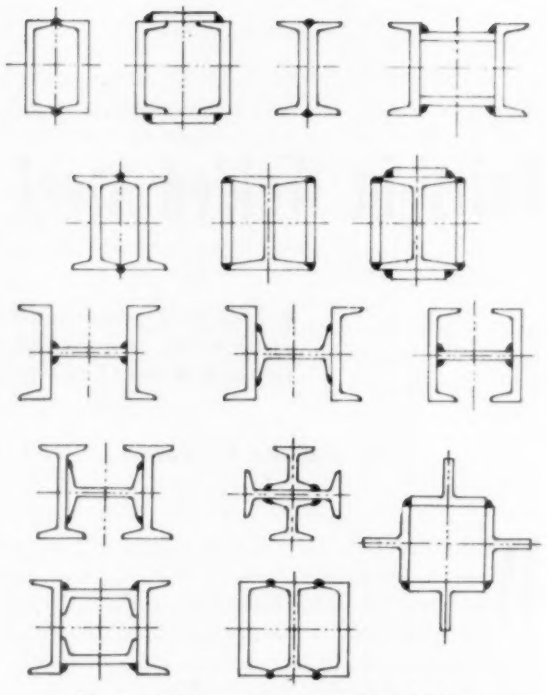


Fig. 1 Columns and compression design

formulas and decreasing the column section weight.

Beams, girders, purlins, etc., can be figured for continuous span action if three or more spans occur in a structure and the proper connections are designed. This is a saving in weight up to approximately 30% under some conditions.

Battledeck flooring systems and metal walls reduce general dead loads, thus reducing beam and column loads, also foundation requirements (see Fig. 2).

Many built-up sections show various degrees of saving in weight, such as T-flanged girders.

2. Simplicity of the design and details: Simplification and weight reduction of details are very pronounced if proper welded design is employed. Cases of particular note are:

(*a*) Wind-bracing connections between columns and

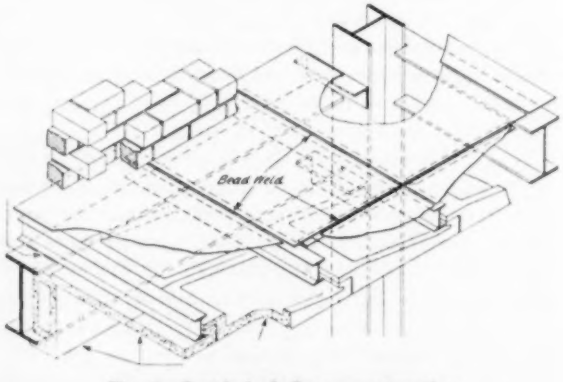


Fig. 2 Battledeck floor construction

beams in tower or skyscraper or factory buildings. Perhaps one-half the former weight can be saved, saying nothing about the almost complete elimination of shop fabrication of these members.

(*b*) Beam seats or brackets, column splices and baseplate connections certainly present worth-while solutions for savings which are being used today.

3. Elimination of noise and vibration during erection: The absence of air hammers and the substitutions of the almost noiseless crackle of the welder's arc are certainly a valuable advantage from the point of view of owners and adjoining property occupants. This feature alone is "gold" during remodeling or the building of additions to libraries, hospitals, schools, office buildings and commercial buildings. Some examples are the reframing of steel work necessary for installation of escalators in our loop stores, Marshall Field & Co. in Chicago being one of quite a list—the work having been done in the 1930's.

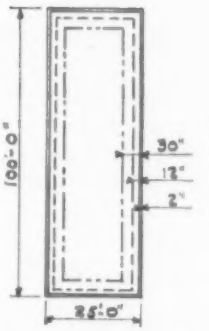
4. Ease in making reinforcements for strengthening deteriorated structures: The elevated structures of Chicago have been reinforced or remodeled by welding since about 1928 or 1929. Railroads repair rusted-out column bases and members of viaduct structures throughout Chicago by our tool for joining metals, saving many dollars.

5. In remodeling buildings and other structures there is, many times, a decided price advantage—especially when the work is designed right and when proper competition is obtained from qualified fabricators and erectors of welded steel work. In new structures this price advantage is often obtained in the same manner. In remodeling work especially there is less cutting out of the work of other trades, resulting in less patching, work can be done during regular work hours eliminating overtime pay rates in the field, and the drilling of field holes can be eliminated.

6. Harmonizing welded work with interior or exterior design: Examples are the welded foot bridges over our outer drives, a building at the Brookfield Zoo, German railroad stations, Aluminum Company of America's new office building in Pittsburgh, welded arches over gymnasiums in a number of school buildings of more or less recent construction.

As the designer of a building interior and the artist concerned with the exterior elevation visualize how welding can economically make artistic lines out of load-carrying members, this new field will be more fully developed and the public will have an opportunity to gaze upon a new trend in decorative art. This need not necessarily be of futuristic design. It offers an opportunity for development of a new school in design perhaps along with the adoption of streamlined wood arch construction.

7. Maximum rigidity in a properly designed welded structure is obtained since as compared to a bolted structure there can be no "give" at joints due to having holes punched or drilled $^1/_{16}$ in. larger in diameter than the bolt used to join a given piece. Rivets if properly



Year	Estimated Weight per Square Foot of Wall	Per Cent Building Area Occupied by Wall
1890	350 lbs.	24.0%
1891	150 lbs.	9.8%
Today	15 lbs.	1.6%

Fig. 3 Space saving and weight saving advantages of metal exterior walls

driven of course fill this space during the driving process, however with more connecting material usually used for a riveted or bolted job there can be more give at joints than where direct connections by welding are made.

8. As stated before, elimination of field drilling in connecting new steel to old reduces costs since welding requires only the exposure of metal on the side to be welded, but bolting or riveting requires exposure of both sides of a member to connect new steel to existing. In finished building interiors where remodeling requires steel changes or additions, this advantage can materially reduce over-all construction costs. An example is the State St. side escalator job at Marshall Field & Co.'s retail store built in 1934.

9. Where close dimension clearances are encountered, many times welding can solve the problem, since welding can be accomplished in less space then rivet driving.

10. Use of battledeck floor systems and metal walls reduce thickness and unit weights reflecting savings when multiplied in large quantities throughout a building. Examples are: the A. O. Smith office building, Milwaukee, which has thin battledeck floor construction; the ALCOA building in Pittsburgh, just completed, has metal exterior walls. For example, prior to about 1890 when steel-framed structures were introduced, masonry walls of buildings perhaps averaged 30 in. in thickness with a weight of about 350 psf of surface. After the use of the steel frame for building construction, these exterior walls were reduced to "curtain" walls of about 12 in. thick weighing about 120 psf of surface. Today metal-insulated walls can be constructed perhaps $2^1/_2$ to 4 in. in thickness weighing 12 to 20 psf of surface (see Fig. 3). Thus, increased interior space is now available to the user and there is a reduction of dead loads in such a structure all the way down to and including the foundation, reducing supporting structure requirements. In the same way metal floors reduce floor thickness from, say, 14 to 18 in. down to 6 to 9 in. and reducing floor dead loads from say 100 psf to 15, or so, psf. By multiplying the areas of all exterior walls and all floors by these savings, the structural designer can readily see where savings that can be

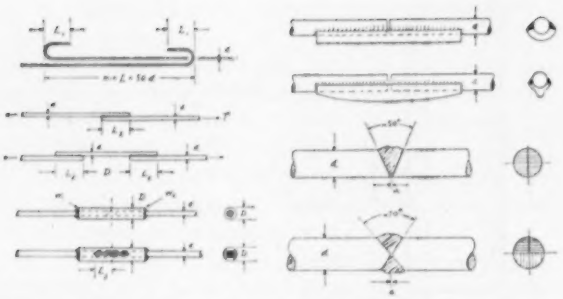


Fig. 4 Details of various types of welded joints for reinforcing bars

made are very important, especially during these high priced times.

11. By using welding, reinforced concrete construction can be remodeled or extended economically, because new reinforcing bars can be welded directly to existing bars (see Fig. 4) with only the necessity of cutting out existing concrete sufficient to expose the existing reinforcing enough to accomplish the welding, while formerly a rule of thumb required exposure of 30 diameters of the bar for proper bond. This reducing of cutting out of concrete with its corresponding omitting of replacement of the concrete after new bars are placed is a decided cast-reducing feature when welding is used for adaptable purposes.

12. Field fabrication instead of shop fabrication can many times be used by an alert designer to reduce ultimate costs to his client. Cost comparisons should be made for each job to determine best uses.

Examples of welded steel structures are too numerous to mention. We see them every day in many cities but few recognize them. Between the years 1931 and 1935, the writer was with a company that had more than 300 such contracts and presumably, they are still serving their respective purposes. One interesting job was the new roof of the LaSalle St. Railroad Station, Chicago in 1933. This structure was erected over live tracks, there being allowed only one dead track at one time. All brackets that support this roof, which is 223 ft wide and 475 ft long, along the east and west sides are welded to the then-existing columns which then supported a high truss arch-shaped roof in cross section. Much concern was made by many engineers at this time, as welding for so important a load-carrying job was new to them. A test to destruction was conducted on one of these brackets to gain their faith. Other typical welded structures are shown in Figs. 5 and 6.

III. PROBLEMS ENCOUNTERED

Problems encountered during fabrication and erection welding mainly concern distortion caused by the heat induced into the metals to be joined by the welding process. Practical methods employed to control distortion of welded products can be summarized as follows:

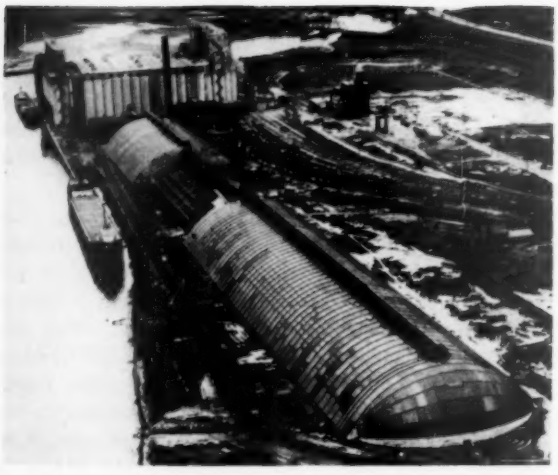


Fig. 5 2200-ft long by 210-ft wide storage buildings in which a considerable portion of the conveyor system along top of curved roofs and the "tent"-shaped covers of steel plate over conveyor trench are welded

Fig. 6 All-welded conveyor systems for transporting sand and gravel

1. Contraction in welding produces bending which is concave on that side of the neutral axis upon which the weld metal is placed. Preheating of smaller parts reduces trouble to a very great extent but usually does not entirely eliminate it, therefore:

2. On thick or heavily restrained material, preheating will reduce cracking. Effect of the preheating is: (*a*) expansion of the base metal due to the preheating reduces the differential contraction between the base and weld metal with a consequent reduction in residual stress. (*b*) Rate of cooling is reduced by preheating; thus metallurgical changes are minimized which could otherwise produce sufficient hardness to cause cracking.

3. Weldments may be subdivided into separate subassemblies free from restraint where distortion effects can be corrected before or during final assembly.

4. Welding should be distributed in the design uniformly about the neutral axes as nearly as practical.

5. The welder should weld from the center toward free ends in both directions.

IV. THE ENGINEER

Now let us turn our attention to the design and the shop drawings for fabrication and erection use—welders' use. The professional approach to welding now is of prime importance. Engineers have it within their power to use welding in their designs, details and specifications. We can obtain product and structure unity by welding. The author believes there should be an increased tempo of action for unity in thought and purpose by and among engineers to better aid our peoples in obtaining better products at lower costs—steps toward ultimate world peace.

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(*Continued from page 216*)

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PRACTICAL WELDER AND DESIGNER

Watch Expansion and Contraction During Welding

Hints for controlling these forces during welding

by B. H. Higgs

IN a recent issue of the Journal, were some basic ideas about how metals expand and contract, and how expansion and contraction can be controlled. Now, let us see what happens to welded joints and how one can control distortion in welding.

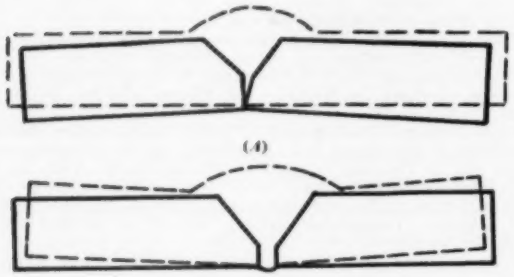

Fig. 1 For butt welds, set the plates out of flat, as shown in (B)

A butt weld is a common type of welded joint. In Fig. 1, two pieces of beveled plate are shown by the solid lines. If no jig is used or the forces are not taken into account, the joint may turn out as shown by the dotted lines in (*A*). In this type of joint there is greater contraction across the top of the joint.

To get a flat joint after welding, the simplest remedy is to place the two plates out of flat in the opposite direction as shown in (*B*). Then contraction will merely pull the plates into a straight line.

In tee or fillet welds (Fig. 2), a common difficulty is that the upright part is pulled out of the vertical, as the dotted lines in (*A*) show. The flat plate may bend as well. To avoid this difficulty, the plate can be preset into the desired alignment (*B*).

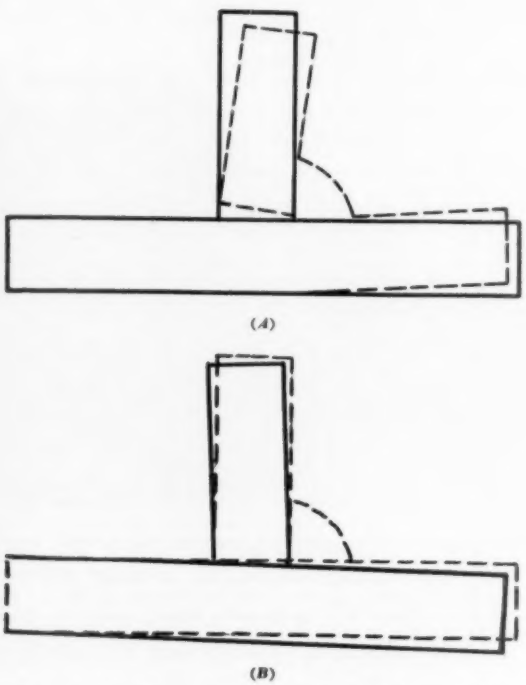

Fig. 2 For fillet welds preset the upright member as shown in (B)

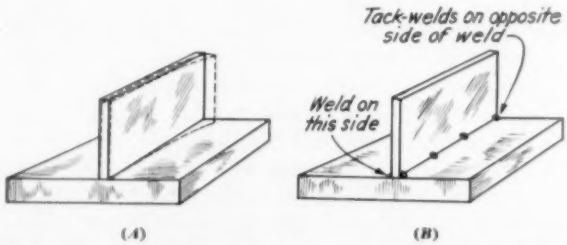

Fig. 3 Tack welds will hold the parts rigid during welding

B. H. Higgs, Linde Air Products Co., Salt Lake City, Utah.

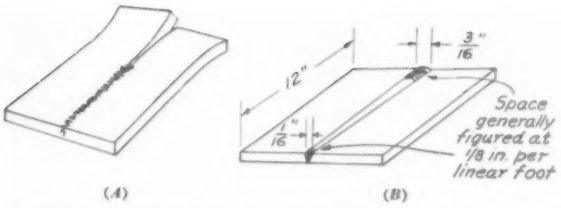

Fig. 4 Proper spacing will eliminate overlapping and distortion

Also, in fillet welds, especially in this metal the parts may move out of alignment as shown in Fig. 3. Tack-welds along the side opposite the weld will go a long way toward controlling this distortion. A jig that will hold the parts rigid during welding is most effective.

If two plates are welded together, as shown in Fig. 4, without tacking or some other form of restraint, distortion would cause them to overlap. This can be avoided by allowing a little more space at the far end, and tacking.

Combination Welding and Forming Machine

by John Maloney

THE demand for a combination forming machine and welding machine has been answered through the joint efforts of the Struthers Wells Corp. and the Federal Machine and Welder Co. Machines are presently being produced to form and weld a wide range of appliances, cabinets and liners. The combination machine consists of a Struthers Wells Quadruplex Tangent Bender with a Federal Machine and Welder Co. Welding Component mounted on a beam which is raised and lowered with each machine sequence to make the forming operation possible.

The material is first placed in the lower dies of the bending machine and then the operator presses a button to start the fully automatic forming and welding cycle. The bender forms the cabinet to the desired shape and the last bender operation actuates a limit switch which initiates the automatic welder cycle. At this point, the welder beam is lowered and automatically latched to the male bender die. The welding guns then engage the cabinet and make the welds. The guns retract, the beam unlatches and raises to dwell position. At the time the welding beam starts to retract the bending wings of the tangent bender also return to their initial position. The cabinet assembly is then automatically lifted to a position where it will easily clear the male die for unloading.

Production costs are materially reduced by an installation of this type compared with conventional methods of forming in a bender and then transferring to a separate weld station. Only one operator is required to perform both operations in this single combination machine.

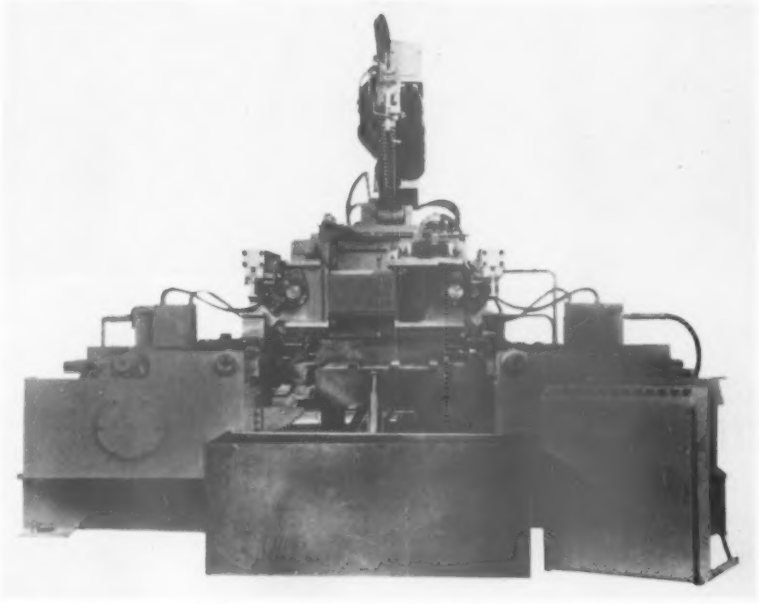

Fig. 1 Combination Tangent Bender with Welding Component—note finished deep freeze liner in foreground

The combining of the welding and bending machine also saves valuable floor space. Not only is the floor space occupied by the welding machine saved, but, also, the large area required to store unwelded assemblies is also saved. This amounts to considerable plant area, particularly in the manufacture of freezer, washer and dryer cabinets, liners, etc.

Since the weld is made while held to size in the bender there is no need for overforming, which also eliminates sizing fixtures. No finer sizing and holding fixture could be found for the welding machine than the die forms of the bending machine. Location problems in the welding machine on these assemblies is eliminated. The welding component shown in the photograph is designed with a series welding circuit, the series die being incorporated in the male die of the bender. For heavy gages, direct welding is used. Units have been designed where the welding guns index, and in this way, the spacing on any series circuit can be enlarged to give the most ideal welding conditions.

A travel-head seam welding component is presently being added to a tangent bender for the manufacture of washing machine tubs. This unit will produce a water-tight weld as required for this particular application.

John Maloney is a Sales Engineer with the Federal Machine & Welder Co.

Groove Cutting for the Shop

by R. G. Householder

A GROOVE-CUTTING nozzle will give you welcome relief from long hours of hard work in removing steel surface metal. Equipment is simple and costs very little. All that is needed is a special groove-cutting nozzle attached to your regular cutting blowpipe or cutting attachment. With this nozzle in your blowpipe you can do practically any job on steel that you can do with hand or pneumatic chisels and grinders.

WHAT IT WILL DO

Groove-cutting jobs can be divided roughly into five classes:

1. Removing tack welds.
2. Removing unwanted metal, such as temporary or defective welds.
3. Grooving edges before welding.
4. Removing surface defects in steel castings or plates.
5. Removing the under side of the first pass when welding is to be done from both sides.
6. Removing metal in alterations, repair, maintenance and scrapping work.

Groove-cutting works best on plates, forgings and castings of steel that has a carbon content of 0.35 and less. Structural steel shapes and the well-known mild or carbon steel plates fall in this group. Other types of steel can be groove cut but special treatment may be required.

R. G. Householder is connected with the Linde Air Products Co., Philadelphia, Pa.

Fig. 1 To do groove cutting, all you need is a special nozzle in a standard cutting blowpipe or cutting attachment

HOW IT WORKS

The process uses the same principles as standard oxy-acetylene cutting but the cutting action in groove cutting does not go all the way through the workpiece. The special nozzle, shown in Fig. 1, has an extra large diameter passageway for the cutting oxygen stream and is so designed that it delivers cutting oxygen at low velocity. The oxygen stream strikes a preheated surface at a small angle and "washes" away the surface. Grooves of various widths and depths are easily made by changing the oxygen pressure and by changing slightly the motion of the blowpipe head.

HOW TO DO GROOVE CUTTING

First, attach the groove-cutting nozzle to your blowpipe or cutting attachment just as you would any cutting nozzle. Set the oxygen and acetylene pressures and adjust the blowpipe flame as you would for hand cutting. The flame should be slightly oxidizing when the cutting oxygen is on.

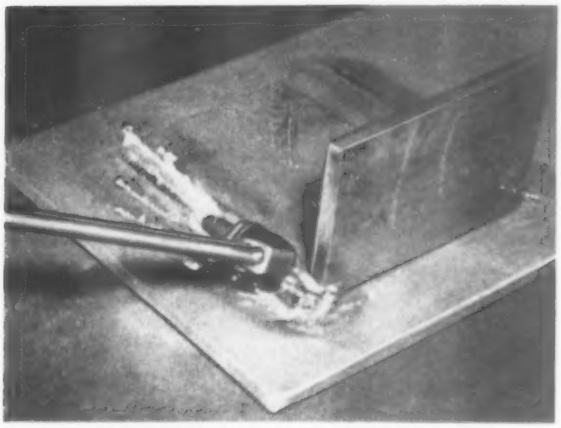

Fig. 2 Welded assemblies are easily dismantled. Welds are removed without damage to parts

Fig. 3 Surface defects in steel castings or plates can be removed quickly and easily

Fig. 4 This photograph shows the casting after removal of the defects

Fig. 5 Defects can be removed from steel plate and grooves can be cut with the groove-cutting nozzle

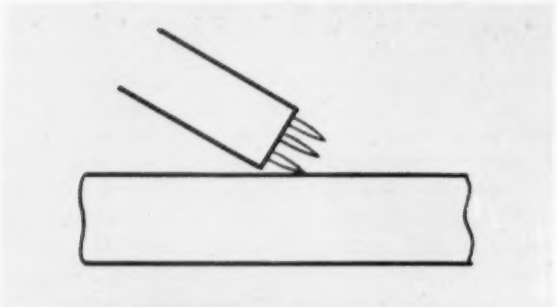

Fig. 6 Hold the nozzle at an angle of between 20 to 40 deg while you preheat the starting spot

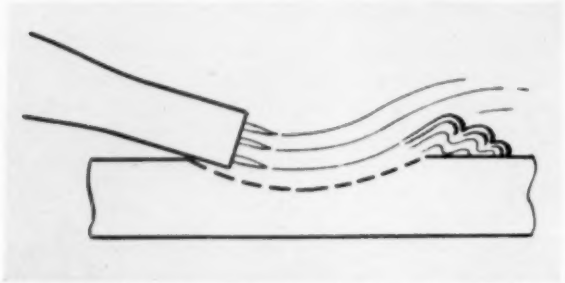

Fig. 7 As the cut starts, swing the blowpipe down in a smooth arc to reduce the angle

Then, preheat the spot at which the groove is to be started. Hold the nozzle at an angle of between 20 and 40 deg in the direction of the cut as shown in Fig. 6. The inner cone should just touch the surface. Maintain the preheat for several seconds until small spots of molten metal appear under the flames. A few orange-colored sparks will also "pop" off the steel surface.

When the workpiece is properly preheated, slowly press down the cutting oxygen lever. As the cut starts, turn the blowpipe in a smooth downward arc. Reduce the angle between the nozzle and the plate as shown in Fig. 7. Carry out this starting operation with a firm easy swing of the blowpipe. Take about 2 sec to move from the preheat to the operating angle.

The operating angle is 5 to 10 deg as shown in Fig. 8. When it is reached, slowly start moving the blowpipe forward. Carry the blowpipe squarely along the surface of the plate—do not touch the groove with the tip of the nozzle and keep the inner cone of the preheat flames $^1/_4$ to $^1/_2$ in. back of the molten metal. You will get the correct blowpipe speed if you keep this distance between the molten metal and the nozzle tip. This is one of the most important things to watch in groove cutting.

REMOVING METAL DEFECTS

Reheat a point slightly behind the defect to be removed. The distance depends upon the estimated depth of the defect. Press down the cutting-oxygen lever and as the cut starts, draw back the nozzle and lower the angle as shown in Fig. 9. Then increase the angle gradually. Direct the cut downward until the defects are reached and removed. Defects will usually appear as either lighter or darker spots in the molten metal. The U-shaped groove which is shown in Fig. 9 is ideal for rewelding. This is an economical fast way to reclaim defects of castings.

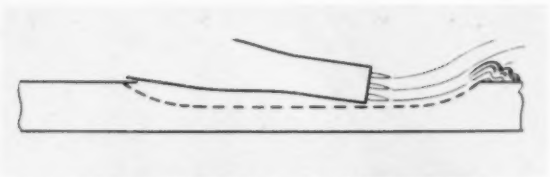

Fig. 8 The operating angle is 5 to 10 deg. Notice that the tip of the nozzle does not touch the plate

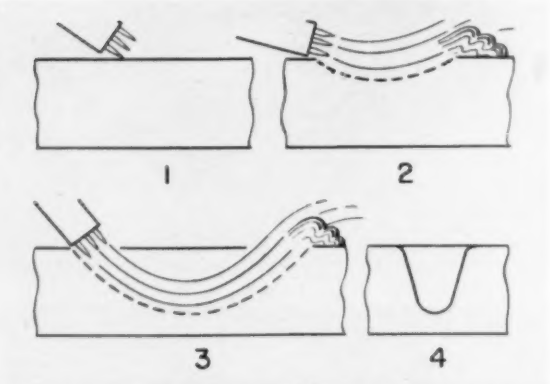

Fig. 9 How to remove metal defects: (1) preheat a point behind the defects, (2) start the cut, draw back the nozzle and lower the angle, (3) turn on the cutting oxygen and gradually increase the angle. Direct the cut at the defects until they are removed. (4) The U-shaped groove is ideal for rewelding

With the groove-cutting nozzle, grooves can be made that are as deep as they are wide or they can be made very shallow. If the cutting-oxygen pressures are too low, the cutting takes on a washing effect, leaving ripples in the bottom of the groove. Oxygen pressures that are too high will advance the portion of the cut nearest the surface ahead of the rest of the molten and the cut will be lost.

For information about the special groove-cutting nozzle see your welding supply distributor. He can supply you with the nozzles as well as any additional help you might need in their proper use.

Brazing Methods for Refrigeration Units

By A. L. Johnson

FOR a number of years we have been successfully rebuilding hermetically sealed household refrigeration units. One operation of great importance which has been improved by steps is that of brazing on the assembly line. When refrigeration units come in to the plant they are completely disassembled. Each part is then individually tested and inspected and all defective parts are scrapped. Rebuilt units will average to contain 25 to 35% new parts (domes, floats, receivers, etc.). This means that a large portion of the joints are new metal.

At the station involved in this discussion the variety of combinations to be joined includes: 1/4-in. copper tubing to 5/16-in. steel tubing; 3/8-in. copper tubing to 3/8-in. swedged copper tubing; 1/4-in. copper tubing to a steel bushing; 1/8-in. copper tubing to a steel fitting. On the copper-to-copper joints a phosphorus-copper brazing alloy is used and on the copper-to-steel joints either a 45 or 47% silver alloy. The problem involved in such joints may seem to be small and easily corrected from a manufacturing viewpoint but in a service organization the tolerances in the brazing operation cannot be held as close as they are in original manufacture.

Fig. 1 Brazed joint made with liquid flux. Note amount of flux left around the joint and the amount blown off and solidified on the top cooling fin of the compressor

During the early operation of the plant we had some small amount of trouble with leaks in the brazed joints. We had found that if we used a silver brazing alloy which had more of a plastic range and therefore was not so fluid we could build a small fillet around the joints, making them stronger—provided we had no flux inclusions. Improper fluxing turned out to be at the bottom of much of our trouble.

When the work was done with paste fluxes diluted with water to make them quite liquid the operators became sloppy with it. They invariably used it too thick, and too much of it. Not only was this wasteful of the flux but it made a hard cleaning job before painting and caused some "flux joints" and numerous flux inclusion pits and holes (Fig. 1). A number of ways were tried to break this habit. A trial of several fluxes that were very liquid showed that this was a

Fig. 2 Brazing station equipped with Gasfluxer

Fig. 3 Using the flame to coat the required joint surface with a thin film of flux

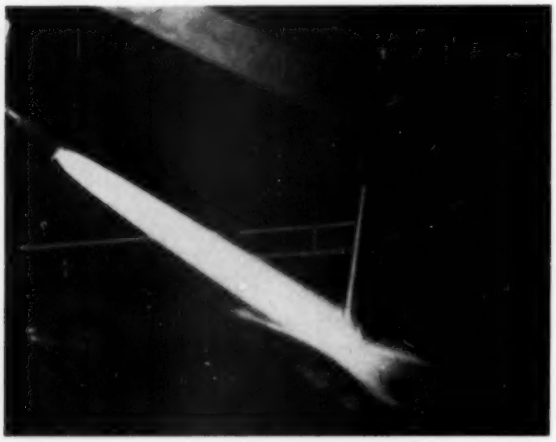

Fig. 4 "Painting" a copper-to-copper joint with flux

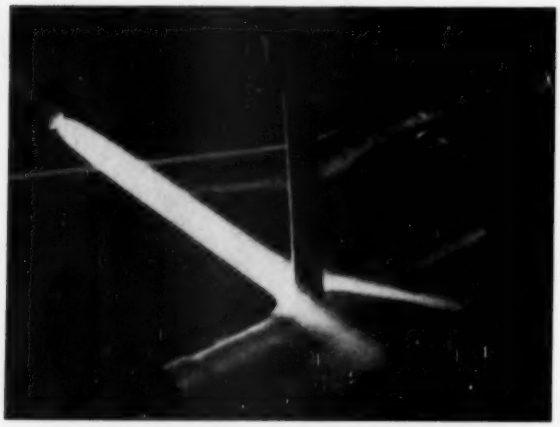

Fig. 5 For proper heating the flame is directed against the heavier of the two tubes

decided help. So we tried the method of giving the operators fluxes that were prepared to a certain pouring consistency each day. At the end of the day this liquid flux was collected and diluted to the proper consistency for the next day's use. This was troublesome and expensive but we were soon able to see improvement in terms of better brazed joints and fewer leak rejects.

At this point we were beginning to be complacent and to think we had reached the peak of excellence until someone suggested that we try using the Gasflux method of passing the fuel gas for the torch through a flux container so that the flux is picked up in a controlled amount and passed into the torch flame. Being open minded to any means of reducing operating costs without sacrifice of quality, we decided to set up one station with a Gasfluxer in the line (Fig. 2). It did not take long to work out satisfactory procedures for use with both the silver alloy and the phosphorus-copper alloy. It had no effect on soft soldering applications where these operations were performed at the same stations along with silver and phosphorus-copper alloys.

Some will question the need of a flux with the phosphorus-copper alloy when used on copper-to-copper joints. It is true that this alloy needs no flux to prevent oxidation in the joint itself, the phosphorus acting as a deoxidizer. However, the tube wall beyond the influence of the phosphorus gets hot and becomes oxidized, discolored and hard, more difficult to handle and bend during assembly. The flux-bearing flame can be used to coat the entire heat-affected area with flux and thus prevent oxidation and preserve the good working properties of the metal. Figure 3 shows the proper method of using the flame to "paint" the area around the joint with a minute coating of flux. Wherever the tip of the flame touches, the surface is sufficiently fluxed.

Figures 4 to 7 show the steps in brazing a $^1/_4$-in. copper tube into a $^3/_8$-in. copper tube. First the assembly of the two tubes is placed in a holding fixture and the tip of the flux-bearing flame is placed around

Fig. 6 When brazing temperature is reached, the phosphorus-copper alloy wire is touched to the joint area

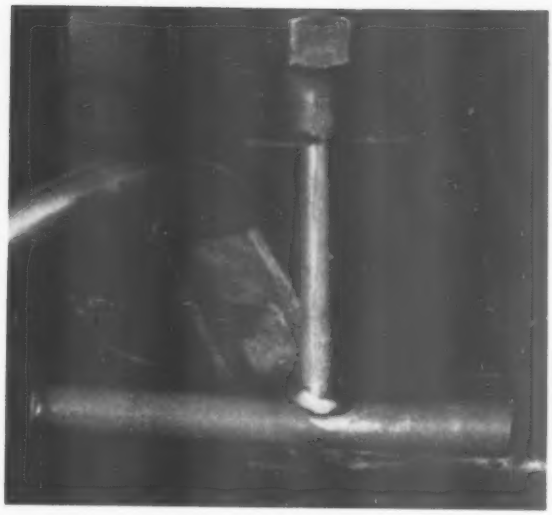

Fig. 7 Clean appearance of the completed joint. The material also retains most of its softness

the joint area to coat it with flux. Next the flame is directed toward the heavier of the two tubes for preheating. As the material reaches the proper heat, the brazing alloy is touched to the joint area. After it flows throughout the joint the flame is slowly withdrawn. The cleanliness and strength of the completed joint are apparent in Fig. 7. On copper-to-steel connections we found that penetration depended upon the amount of fluxing in the initial stage of application of heat.

Since adopting the use of the flux-bearing flame we have reduced the amount of brazing alloy used and have cut out leaks by more than 60%. Our experience has developed the following gains in efficiency: stronger joints through better alloying action of the brazing materials with the base metal; fewer inclusions, gas pockets and voids; less cleaning necessary after completion of joints; lower cost per joint through saving of both alloys and flux; easier for operators to become more expert; less mess and bother around the brazing operation.

Longer Life for Truck Center Castings

WEARING life of locomotive tender truck center castings has been substantially increased on the Illinois Central Railroad by the oxy-acetylene flame-hardening process. This method has practically eliminated abrasion and burring which generally causes center castings to lock together.

An Oxweld W-24-R blowpipe equipped with a multiflame head is used in the process. Castings are machined lightly to a specified diameter in preparation. Male castings are laid flat on a machine-rotated mandrel for face hardening, and on the side for sidewall treatment. Inner walls of female castings are treated in the same manner. The castings are rotated at approximately $3^1/_2$ ipm under the flame and simultaneously water quenched.

Rotation of the casting for uniform flame treating is accomplished by a simple but effective device. A turntable is mounted upon a drum around which a rope is wound. One end of the rope is fastened to an electric-driven spool which rotates at any desired speed, and at the same time, unwinds the rope on the drum, causing it to turn. Further use is made of the spool-drive by mounting the casting on the axle of the spool for flame hardening the sides.

Fig. 1 Life of this truck center casting is increased three to four times by flame hardening

Truck center castings consist of cast steel of approximately 0.25 carbon content. They average 129 Brinell before hardening, and 300 Brinell after being treated. Depth of the flame-hardened area ranges from $^1/_8$ to $^1/_4$ in.

Illinois Central Railroad estimates flame hardening increases center casting life three to four times. The setup is easy to operate, speedy and the castings require no finishing.

the AMERICAN WELDING SOCIETY

activities • related events

Western Metal Exposition and Congress

Twelve intensive technical sessions have been programmed by the AMERICAN WELDING SOCIETY'S LOS Angeles chapter as features of the Western Metal Congress and Exposition to be held in Los Angeles March 23rd to 27th.

Sessions of the congress will take place in the Hotel Statler and the exposition with more than 275 exhibiting firms in Pan-Pacific Auditorium. The combined events are being held by the American Society for Metals with the cooperation of AWS and 18 other western sections of national technical societies.

The WELDING SOCIETY sessions will be of two to three hours' duration and will be held mornings, afternoons and evenings of the Congress-Exposition.

Sessions for March 23rd will be held on structural welding, pipe and pressure vessel welding and industrial welding.

Under structural welding, the subjects will be distortion control, economical design and jigs and fixtures. Arc welding of low chrome molybdenum steels, inert arc welding as applied to piping and cause and correction of microcracking during the weld are topics for the pipe and pressure vessel session.

Electrode coatings for stainless and mild steel, control of welding and nondestructive testing will be listed for the industrial welding session.

Submerged arc welding—flux type, automatic arc welding—inert gas type and aircraft and rocketry fusion welding are set as session headings for the second day and evening.

Structural members, 3 o'clock welding and relation of technique to penetration and dilution are subjects of papers on the submerged arc session.

The automatic arc meeting will hear papers on shielding mixtures for inert gas welding, copper alloys, silicon bronze, aluminum bronze and the welding of carbon steels.

High-strength joints in low-alloy steels, manual and automatic welding of aluminum and welding of high-strength aluminum alloy castings will be described under aircraft and rocketry.

Another session dedicated to aircraft flash and pressure welding will include the topics, "Flash Welding Tooling and Application," "Pressure Welding Tooling and Application" and "Specification Comparisons."

Subjects pertaining to titanium and stainless fusion welding will include welding of NAX and stainless steel, development of rockets through welding and titanium fabrication.

A session on spot and projection welding has listed papers on military specifications, welding techniques and quality control in spot welding for aircraft.

Under brazing and bronze welding will be the topics: "Vacuum Brazing of Clad Steels," "Titanium Brazing" and "Atmospheric Controlled Brazing."

A session on resistance welding and cutting will cover heavy steel sections, gas and powder cutting of carbon and stainless steel and hard facing techniques.

The concluding program on the morning of March 27th will be dedicated to welding research. Papers will be presented on "what's new" in arc, inert gas and pressure welding.

Admission to all sessions of the Metal Congress will be free to interested parties. All who have membership cards in AWS or other cooperating societies may walk right into the exposition. Special invitations to others are being mailed by exhibitors.

Specifications for Brazing Filler Metal

(9 Pages, Issued Jointly by American Society for Testing Materials and American Welding Society)

Issuance of the *Specifications for Brazing Filler Metal* brings the total in the series of filler metal specifications issued to date to eight. These new specifications are especially important because they cover a field which has grown by leaps and bounds and has not heretofore been covered by specifications, except for a few specific materials.

The Brazing Filler Metal Specifications cover every type of brazing filler metal in common use today. The 33 different classifications are divided into groups according to the principal constituents. They include classifications for aluminum-silicon; copper-phosphorus; silver; copper-gold; copper and copper-zinc; magnesium; and heat-resisting filler metals.

The Specifications, as usual, include an appendix giving helpful information for the selection of the brazing filler metal best suited for a given application. Among the factors included are the brazing temperature range for each classification, the color of the joint obtained, recommended joint designs and an explanation of some of the fundamental concepts of brazing which have previously been misunderstood.

Copies of the *Specifications for Brazing Filler Metal* can be obtained, at 40 cents each, from either AMERICAN WELDING SOCIETY, 33 W. 39th St., New York 18, N. Y., or American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa.

Rules for Welding Piping in Marine Construction—Carbon Steels

(12 Pages, Illus., Published by American Welding Society)

The increase in use of marine piping, hence increase in experience, is reflected in the new edition of the *Rules for Welding Piping in Marine Construction—Carbon Steels*, which is a revision to the 1948 edition of the same standard.

The revisions included in the 1953 edition represent changes and clarifications of the requirements agreed upon by the "Enforcement Authorities" in the Shipbuilding industry: American Bureau of Shipping, U. S. Navy Department and U. S. Coast Guard.

The new Rules include typical joint design details for splices, branches and nipples. An X-ray standard for evaluation of weld quality has been added. Specific electrode requirements as to classification and sizes for different positions of welding are now included as is an expanded description of weld quality and weld defects.

As revised the Carbon Steel Piping Rules parallel, in content and arrangement, the corresponding Rules for Ferritic Alloy Steels issued in 1952.

Copies of the *Rules for Welding Piping in Marine Construction—Carbon Steels* are available,at 50 cents each, from AMERICAN WELDING SOCIETY, 33 W. 39th St., New York 18, N. Y. The usual discounts to AWS members apply.

NEWS OF THE INDUSTRY

Stress Analysis Meeting

The Society for Experimental Stress Analysis will hold its Spring Meeting, on May 20–22, 1953, in the Hotel Schroeder, Milwaukee, Wis.

Liquid Oxygen Plant Near Camden

Air Reduction Sales Co. will soon begin construction of a new liquid oxygen plant in Riverton, N. J., ten miles northeast of Camden, it was announced recently by H. R. Salisbury, president.

The new plant, which is scheduled to begin production next year, will primarily serve the Delaware River Basin industrial area. Deliveries of liquid oxygen supplementing the production of other Air Reduction plants, may be made north to New England and south to the Carolinas.

In full production, the plant will employ upward to 100 persons and with related facilities will represent an investment of several million dollars.

In addition to oxygen, the plant will also produce nitrogen and argon. The oxygen will be used principally in the oxy-acetylene processes for the cutting and welding of metals. Argon, an inert gas, is used primarily in the gas-shielded electric arc process and the electronics industry. Nitrogen, also an inert gas, provides an inert atmosphere where fire hazard or chemical oxidation must be avoided.

Air Reduction Sales Co. is a division of Air Reduction Co., Inc.

Smith Welding Equipment Corp. Expands

The increased research and engineering facilities that Smith Welding Equipment Corp. of Minneapolis has outlined for its long-range program of product development and sales expansion will be provided by 6000 sq ft of new construction.

The new wing on the present company building practically doubles the Engineering and Experimental Departments and will also provide additional facilities for quality control and increased tool production.

Products of Smith Welding Equipment Corp. have national distribution, and the company has been known for its long record of inventiveness and precision manufacture of commercial and industrial welding equipment (both oxy-acetylene and electric welding). Many of the important improvements of recent years in welding equipment have been attributed to the development work carried on in the Smith engineering departments, and it is expected that this new research laboratory will intensify effort for even better Smith equipment and techniques.

National Cylinder Merger

The boards of directors of National Cylinder Gas Co., Chicago, and The Girdler Corp., Louisville, have, respectively, authorized the managements of the companies to proceed with a proposed plan for a merger, it was announced recently by Charles J. Haines, President of National Cylinder Gas Co., and George O. Boomer, President of The Girdler Corp.

Under the proposed plan approved by the directors of both companies, one share of The Girdler Corp. common stock will be exchanged for 3½ shares of National Cylinder Gas Co. common. Stockholders of both companies will be asked to approve the proposed plan at separate meetings to be held in the latter part of April or early in May.

National Cylinder Gas Co. is a leading producer of oxygen, acetylene and other industrial gases, as well as welding and cutting equipment. The Girdler Corp. is a major manufacturer of processing equipment used in the chemical, food, textile and other industries, and also manufactures high-frequency heating apparatus. It also designs and builds petroleum, gas and chemical plants.

Mr. Haines and Mr. Boomer said the merger will be advantageous to both companies, resulting in wider diversification of products and services. Consideration of merger possibilities grew out of common ownership by the two companies of Tube Turns, Inc., Louisville, pioneer manufacturer of seamless welding fittings and flanges.

Eutectic Receives Award of the Month

A plaque was presented recently to Rene D. Wasserman, President of Eutectic Welding Alloys Corp., Flushing, N. Y., for the outstanding "new product" of the month by Richard A. Gagney, eastern representative for *Mill and Factory* magazine.

Each month the editorial board and engineering judges of this magazine select the product they consider has made the most valuable contribution to industry. In evaluating the many products submitted all factors are taken into consideration and variety of applications and savings in time and money are among the desirable characteristics necessary to win this coveted award.

"ChemoTec," the new organic bonding agent which is the result of many years of research, was selected out of some 250 new products reviewed. The Eutectic Welding Alloys Corp., known throughout the world for its welding alloys and electrodes, has always endeavored to anticipate the needs of industry. It was a long felt need that instigated the original "ChemoTec" research program. In the higher heat ranges, from arc welding down to soft soldering, alloys had been developed that adequately met practically any situation that could arise in the field of metal bonding. However, below soldering temperatures there was literally nothing of a comparable nature and the corporation determined to fill this gap.

"ChemoTec" was the answer. It was possible with this material to join practically any material, dissimilar metals, glass, ceramic, rubber, etc., from room temperature up to 500° F. with a bond strength in excess of many solders. The gap was filled and another industrial problem solved.

New Aid for Welding Instruction

A new series of film strips on arc welding for use by instructors to introduce students to the welding process, welding equipment and where and how it is used is now available through The Lincoln Electric Co. of Cleveland, Ohio. The series of 3 strips, produced in full color and with a supplementary manual, is designed for the instruction of high-school students, vocational trainees, technical apprentices and farmers in the fundamentals of arc welding.

The series, called Arc Welding, consists of three 50-frame strips: "Electric Arc Welding and How It Helps Man," "Selecting and Using Arc Welding Equipment Safely" and "Practicing Arc Welding." The series, produced to be an aid to all persons instructing welding, gives, in full-color photographs and art work, a visual presentation of the historical development of welding, how the process works, what equipment is needed and how it is used. Preliminary steps in making basic joints are illustrated with particular emphasis on safe welding practices. Close-up photographs of the welding arc in action show

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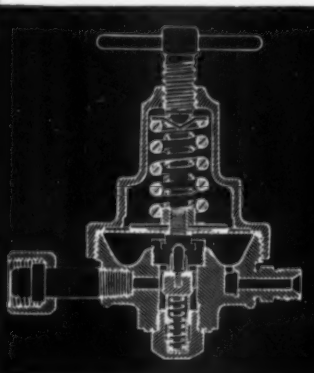
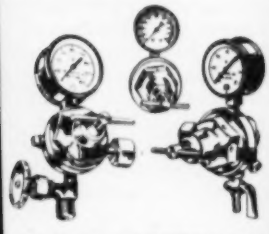


in types for Oxygen, Acetylene, CO_2, Air, Fuel Gases.

"BUILT FOR BETTER SERVICE" with improved diaphragms, replaceable, self-aligning seats; sturdier construction; shatter-safe gauges; alert safety valves and other advantages.



THERE IS A DOCKSON DISTRIBUTOR NEAR YOU—Let us send you his name and our complete catalog of DOCKSON WELDING and CUTTING EQUIPMENT.

Dockson CORPORATION
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each step of how to hold and move the electrode as well as how to prepare and make welded joints in several welding positions. Sequences are designed to supplement and clarify class instruction and demonstration.

The strip was made by Lincoln Electric in cooperation with the Audio-Visual Division of the Popular Science Publishing Co. Conveniently boxed and with supplementary manual, the price is $19.50 for the set of three films.

Radiation Hazard

Exposure to radiation, a growing hazard in industry, can be controlled and injury to health prevented, according to Saul J. Harris, New York physicist associated with the New York State Department of Labor's division of industrial hygiene.

Mr. Harris participated in a panel on occupational cancer, a feature of the third and final day of the 13th annual Congress on Industrial Health. The Congress, held in the Drake Hotel, was sponsored by the Council on Industrial Health of the American Medical Association.

Radiation is a known cancer-producing agent, he pointed out. Exposure to a dangerous dosage may occur in two ways, he said. One is the absorption of radioactive materials into the body by ingestion or inhalation, and the other bombardment of the body with alpha, gamma and other dangerous rays.

The atomic age has brought new possibilities of exposure, he pointed out, adding:

"The defense effort has definitely accelerated an already developing trend toward the use of a variety of sources of radioactivity in industry, particularly the use of such equipment for inspection purposes.

"The examination of welds and metal castings for flaws by the use of radium and X-ray has become routine in foundry operations in New York State. Radioactive cobalt is being used increasingly for this purpose. The use of betatrons for inspection purposes is also steadily gaining favor in industry.

"The fluoroscope has not only made its way into retail shoe stores, but it is being used in industry as an inspection device—for the detection of misplaced nails in shoe manufacture, for example, or the detection of foreign bodies in packaged foods.

"Radioactive static eliminators are finding an increasing market in plants having potential fire hazards due to accumulations of static. Radioactive isotopes are stepping out of the expert hands of technical personnel in research laboratories, and are now coming to be used by lay workers who are not familiar with the potential hazards to health or with the precautions which must be taken."

Mr. Harris said that the effects of repeated exposure to radiation are cumulative, that individual susceptibility differs, and that there may be a long latent period between exposure and clinical manifestations of injury to health.

"Moreover," he added, "exposure to radiation is particularly insidious because we are not endowed with any sensory perception for radiation and so can be subjected to a dangerous amount without being aware of the presence of radiation."

"Natural" radiation may come from cosmic rays or from radioactive materials in the earth, according to Mr. Harris.

Annual Report

The 91st Annual Meeting of the Board of Managers and Members of the American Bureau of Shipping was held January 27th in the Bureau's board room, 45 Broad St., New York City.

Walter L. Green, President, presided and expressed to more than 70 managers and members his appreciation of their attendance.

In his remarks, Mr. Green said:

Bureau Activity

"On Jan. 1, 1953, 226 seagoing vessels of 3,113,600 gross tons and 9 Great Lakes vessels of 103,300 gross tons were under construction and/or under contract to be Classed with the Bureau. In addition, there were 455 smaller miscellaneous type vessels aggregating 120,511 gross tons also contracted for to be built under the supervision of the Surveyors to Class with the Bureau. This new construction totals 690 vessels of 3,337,411 gross tons, which is a 27% increase over the totals of one year ago. On Jan. 1, 1952, contracts were in existence for the construction of 568 vessels of 2,734,896 gross tons to Bureau class.

"There now exist in class with the American Bureau of Shipping, 8500 vessels of 37,404,274 gross tons, of which about 20% are temporarily inactive. To this figure there will be added 738 vessels completed or under construction on January 29th in American and foreign shipyards, these aggregating 3,580,000 tons, making a grand total of 9238 vessels of 40,984,274 gross tons. While a substantial percentage of these vessels are foreign owned and/or registered, the large majority fly the American flag. These figures include seagoing tonnage, Great Lakes and river craft, both self-propelled and nonpropelled. During the past year a considerable number of existing foreign-owned vessels were Classed by the Bureau.

"A total of 270 vessels were completed to American Bureau of Shipping Classification in United States shipyards during 1952, these totaling 514,568 gross tons. Of these, 31 were large merchant vessels totaling 398,750 gross tons. This represents a marked increase over 1951 when only 10 large vessels of 147,569 gross tons were completed. In addition, 239 smaller

miscellaneous vessels totaling 115,818 gross tons were completed to Bureau Class in United States shipyards in 1952.

"A total of 530 new vessels of 1,286,985 gross tons are now on order in United States shipyards to be built to American Bureau of Shipping Classification. Of these, 81 vessels of 1,066,342 gross tons are ocean-going cargo ships and tankers, 9 vessels are for Great Lakes service including 8 bulk ore carriers and 1 freight car, passenger and cargo ferry, and 440 are miscellaneous vessels such as tugs, towboats, barges, etc.

Technical Activities

"The Technical Staff has continued to be very active in dealing with a large number of plans submitted for review and approval not only in connection with the large number of ships now being built to our classification in the United States and abroad but also in connection with contemplated new designs. A milestone in the history of the Bureau was the classification this year of the outstanding Transatlantic liner S.S. *United States*. The classification of this vessel represented the culmination of more than four years of work on the part of the Technical Staff in reviewing early preliminary designs and in collaborating with the Builders and Owners in the development and approval of the actual working plans, and in the consideration of various problems which arose from time to time as the construction progressed.

"As is usual, the Bureau's staff maintained representatives on many Committees during the past year and much time has been given to these activities. Such Committees are the Technical and Research Committees of the Society of Naval Architects and Marine Engineers, the Ship Structure Committee and Subcommittee, several Committees operating under the Welding Research Council and the American Society for Testing Materials, the American Society of Mechanical Engineers, the Society of Refrigerating Engineers, the American Institute of Electrical Engineers, the American Standards Association, the International Electrotechnical Commission, the National Safety Council and several Navy Advisory Committees.

"Since the war there has been a steady increase in steam temperatures on turbine-driven vessels until now practically all new construction is being designed for temperatures between 850 and 900° F. This has made it necessary to use alloy steels for the high-temperature piping and the installations are being made in accordance with the Bureau's 'Interim Guide for the Installation of High-Temperature Piping on Ships.' This 'Interim Guide was formulated in 1950 since at that time there were in existence no standards covering installations in this temperature range. Various organizations are still working on corresponding Codes and it is gratifying to note that they parallel very closely the requirements of the Interim Guide.

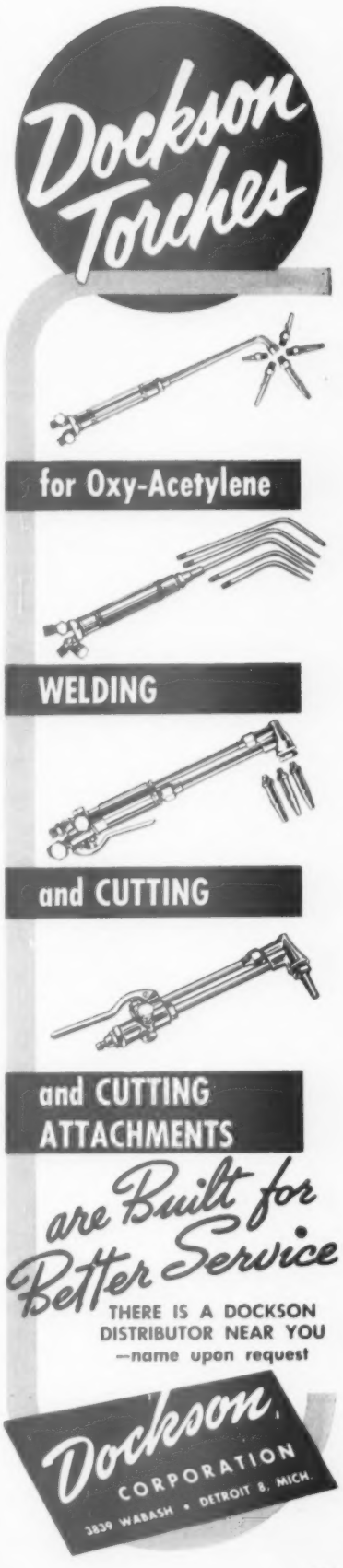
"In the field of materials the action which was taken by the Bureau in 1947 in adopting revised specifications for hull steel plates has continued to be justified not only by the service records of the vessels in which there were used the improved materials obtained under the new specifications, but also by continued research projects. There has been growing recognition of these specifications in other fields of heavy plate structures where in recent years the need for improvement over previous standard steel specifications has likewise become apparent. D. P. Brown, our Senior Vice-President and Technical Manager, attended the Annual Meeting of the International Institute of Welding held in Gothenberg last fall and while there he had the opportunity of discussing with representatives of Shipbuilders as well as those of other industries throughout the world the views of this Bureau in attaching great significance to the necessity of obtaining high-quality materials, particularly in welded ships' hulls. During his trip he had the opportunity of visiting a number of shipyards in the British Isles and on the Continent. He reports that he found splendid cooperation between the shipyards and our Surveyors providing technical services and the inspections during the construction of the vessels building to our classification.

"As reported at the Annual Meeting last year, the Committee on Engineering recommended that the Bureau establish a Special Advisory Panel on Manganese Bronze Propellers to study material specifications, foundry practices and methods of repair or reconditioning with a view toward making recommendations to improve the experience with propellers made of this material. There have been several meetings of the various subgroups of this Panel which have been investigating specific phases of the problem. The work is still continuing and while, as yet, no formal recommendations have been made, advantage has been taken of some of the discussions in already initiating some changes in practice. The use of a new inert-gas-shielded arc-welded process has been tried in several instances in order to find out whether or not this will improve experience with welded repairs."

AISC Meeting

The fifth annual National Engineering Conference of the American Institute of Steel Construction will be held in Detroit, April 22–23.

Sessions will be held in the Detroit Engineering Society Building, 100 Farnsworth Ave., while hotel headquarters will be at the nearby Park Shelton, 15 E. Kirby.



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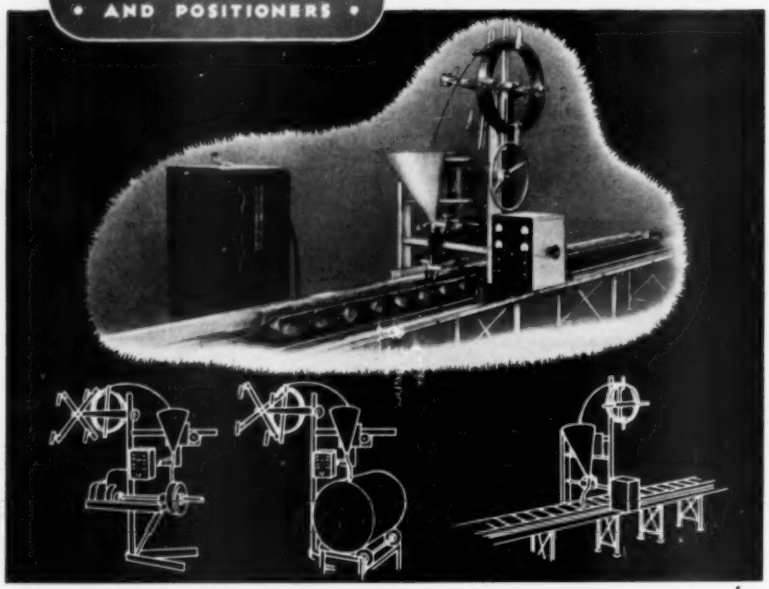
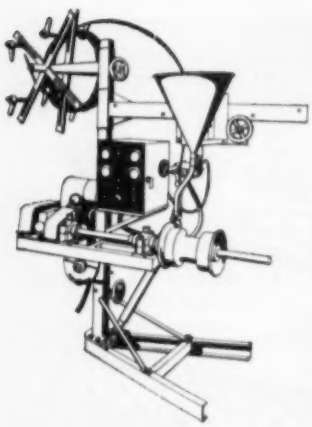


Here's fast, low-cost welding that is *truly* automatic. Rexarc Welders and Positioners are designed for welding on all types of longitudinal or circular surfaces, such as crawler type tractor rails, scraper blades, structural shapes, fabrications, rollers, sheaves and shafts. All types of positioners for special applications will be engineered upon request.

Outstanding features include: provision for both low and high voltage welding; high frequency starting and stabilization, assuring a steady arc at all times; control over low arc voltage and amperage, which minimizes stress and dilution of parent metal. Welding can be lineal or cross-bead on flat or circular shapes, continuous or in sequence. Removable head is transferrable from one positioner to another.



WELDING ON CIRCULAR SHAPES

Welding on shafts, rollers, sheaves, idlers and similar circular surfaces is simple since rotating spindle is vertically adjustable to accommodate a large range of work sizes. Angular positioning for welding idler and roller flanges, crusher mandrils and similar applications is accomplished by hydraulically controlled elevating device. For welding on long circular work, supporting trunnions equipped with friction bearing rolls are available.

SEE YOUR WELDING SUPPLY DISTRIBUTOR OR WRITE, WIRE OR PHONE

THE SIGHT FEED GENERATOR COMPANY
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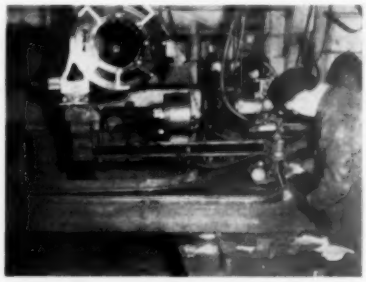
Special Jig for Welding "Goosenecks"

When the Olsen Manufacturing Co., of Boise, Idaho, took on the job of fabricating 150 automotive trailers, the welding of two "goosenecks" on each trailer looked like a difficult fabrication problem. Due to the size of the machine carriage in their shop, the weld could not be completed in one setup, and special positioners would make the job unprofitable.



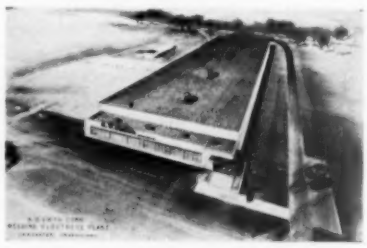
A radial arm support eliminates the need for costly positioning devices and allows for Unionmelt welding of "goosenecks" from one setup.

With the help of Linde Air Products Co., the problem was solved. A Unionmelt welding head was mounted on a radial arm support, as shown in the accompanying photograph, and a simple track was made for the drive wheel of an Oxweld CM-16 machine carriage. With this apparatus and guiding arrangement, the required welds are made quickly and easily. More than 6 miles of high-quality welds have been made on similar "goosenecks" since this equipment was installed.

A. O. Smith Expands

The A. O. Smith Corp. has started construction on a new electrode plant at Lancaster, Pa., to supply a rapidly expanding market for welding electrodes in the east.

Described as "ultra modern," the plant will be nearly automatic in operation. L. T. Hickey, manager of the welding division said.



Although the one-story building will have only 41,000 sq ft of floor space it is on a 10-acre tract, purchased from the Pennsylvania road. This extra space will allow for future expansion. At the outset about 40 workers will be employed.

YOU'LL WELD MORE AT LOWEST COST with

A.O.Smith CHALLENGER

200-, 300- OR 400-AMP. A.C. WELDER

- **Greatest amperage** range in its price class. Example: the 400-amp. model has 510-amp. welding range.
- **75-volt** open circuit: easier-striking, smoother arc; welds *all* electrode types.
- **Needs no boosters,** starters or short-lived gadgets. Easy, low-cost maintenance.
- **Performance-proved** on 24-hour production welding assignments.
- **Costs less** to buy, own and operate.

For complete data on this high-performance, industrial welder, and on the complete A. O. Smith machine, electrode and accessory line, see your A. O. Smith distributor or write A. O. Smith Corp., Welding Products Division, Dept. WJ-353, Milwaukee 1, Wis. *International Division: Milwaukee 1, Wis.*

MADE BY WELDERS . . . FOR WELDERS

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CORPORATION

Hickey said that the Pennsylvania location would make possible a substantial freight cost saving and improve delivery service to customers.

At present all A. O. Smith's electrode manufacture is done in the Milwaukee plant. All nonproduction functions of the welding division will stay here. The new plant will represent additional production —electrodes will continue to be made here.

The latest types of equipment, such as extrusion presses and furnaces, will be used in the new plant, making possible an output of millions of pounds monthly. A. O. Smith originated the process of extrusion and coating of bare wire in the fabrication of welding electrodes. The humidity in the coating and storage rooms will be strictly controlled.

National Cylinder Expands

National Cylinder Gas Co.—Pacific Coast, subsidiary of National Cylinder Gas Co., has moved into its recently completed building on Pacific Blvd., Los Angeles.

The new structure contains approximately 19,500 sq ft of floor space, 12,000 for warehousing and 7500 for offices. The move is a consolidation of separate warehouse and office facilities formerly operated in this city.

Oxygen, acetylene, hydrogen and nitrogen, supplied by the subsidiary's Compton plant near Los Angeles, will be distributed from the new building. Carbon dioxide and dry ice also will be handled. The building will be headquarters for both the Los Angeles district and the Pacific division sales offices.

National Cylinder Gas Co., the parent firm, has general offices in Chicago. It is a major producer of oxygen, acetylene and other industrial gases, as well as welding and cutting equipment. The company operates 75 gas-manufacturing plants in the United States, and has similar type plants in Canada, Venezuela and Colombia.

Women Fabricate Jets with Heliarc Welding

Rosie the Riveter did a magnificent job of replacing man power during World War II. And today, with America's defense needs again in the foreground, Wilma the Welder is doing an equally spectacular job. One plant at which women are doing most of the welding is at Twigg Industries, Inc., Brazil, Ind. This plant produces vitally needed components for fuselages and engines of jet-propelled airplanes.

The majority of parts manufactured at

Fig. 1 Two threaded inlets are joined to an oil sump for an air shield by women welding operators. All three parts are stainless steel. The welding operator has no difficulty in getting the head of a Heliarc HW-9 welding torch into this confined joint

Tempilstiks°

Booth No. 353
Western Metals Show
Los Angeles

the amazing Crayons that tell temperatures

Simply mark your workpiece with the proper Tempilstik°. When the mark melts, the specified temperature has been reached.

Available in these temperatures (°F)				
113	263	400	950	1500
125	275	450	1000	1550
138	288	500	1050	1600
150	300	550	1100	1650
163	313	600	1150	1700
175	325	650	1200	1750
188	338	700	1250	1800
200	350	750	1300	1850
213	363	800	1350	1900
225	375	850	1400	1950
238	388	900	1450	2000
250				

$2 each

Also available in pellet or liquid form

A convenient method of controlling working temperatures in:

- WELDING
- CASTING
- FLAME-CUTTING
- MOLDING
- TEMPERING
- DRAWING
- FORGING
- STRAIGHTENING
- HEAT-TREATING IN GENERAL

FREE — Tempil° "Basic Guide to Ferrous Metallurgy" — 16¼" by 21" plastic laminated wall chart in color. Send for sample pellets, stating temperature of interest to you.

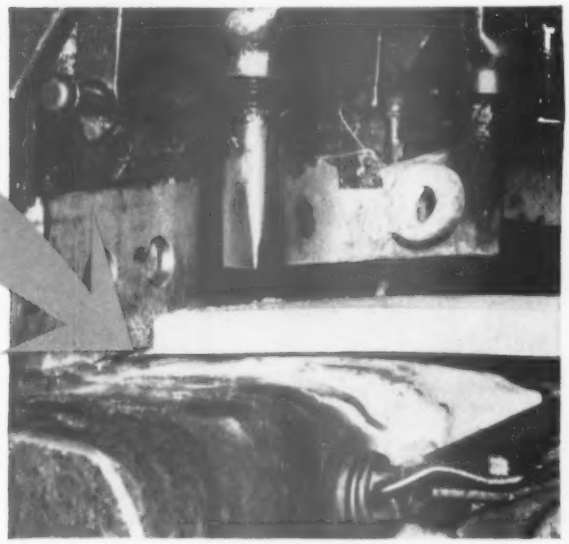
TEMPIL° CORP., 11 WEST 25th STREET, NEW YORK 10, N. Y.

We invite inquiries from reputable distributors interested in handling Tempil° products.

HOT SHEAR BLADES STAY SHARP...when Hard-Faced with HASTELLOY Alloy C

TRADE-MARK

A 3/32-in. deposit of HASTELLOY alloy C on the cutting edge of this shear blade has increased its life by four times. The edge can be rebuilt again and again, when it finally does wear.



This shear blade is used in a plant producing tough non-ferrous alloys. Before hard-facing was adopted, the blades would chip, lose their edge, and have to be scrapped after shearing only about 50 tons of metal. They now can handle roughly four times that amount of metal because they are protected with HASTELLOY alloy C. They can be machined and hard-faced again when they finally do wear. One set of hard-faced blades has been in use in the plant for more than three years with periodic maintenance.

In steel mills, too, HASTELLOY alloy C has increased the life of blooming mill shears by as much as 10 times. Hard-faced blades have lasted 110 turns without maintenance.

HASTELLOY alloy C rod has also been applied to many other hot-working parts with outstanding success. The metal flows well by metallic arc welding or HELIARC welding without preheating. No peening is necessary. Deposits of HASTELLOY C work-harden in service. They can be machined by conventional methods.

For information on how to apply HASTELLOY alloy C to hot-working parts, write for a copy of "HAYNES Hard-Facing Manual." For on-the-job help in applying the rod, get in touch with the nearest District office.

HAYNES alloys

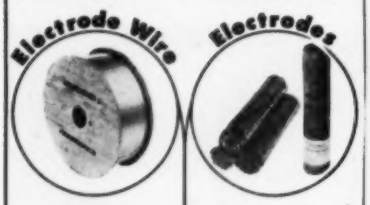
TRADE-MARK

"Haynes," "Hastelloy" and "Heliarc" are trade-marks of Union Carbide and Carbon Corporation.

Haynes Stellite Company
A Division of
Union Carbide and Carbon Corporation
UCC
General Offices and Works, Kokomo, Indiana
Sales Offices
Chicago — Cleveland — Detroit — Houston
Los Angeles — New York — San Francisco — Tulsa

Weldwire Company Inc.

WELDSPOOL WELDBEST



INERT GAS WELDING	MANUAL ARC WELDING
ALUMINUM	
Weldspool 43S	Weldbest 43S
Weldspool 25	Weldbest 25
Weldspool 52S	Weldbest 52S
TITANIUM	
Weldspool 930	
STAINLESS	
Weldspool 304 ELC	Weldbest 307
Weldspool 308	Weldbest 308
Weldspool 309	Weldbest 309
Weldspool 309 Cb	Weldbest 310
Weldspool 310	Weldbest 316
Weldspool 316	Weldbest 330
Weldspool 321	Weldbest 347
Weldspool 347	Weldbest 349
Weldspool 349	
STRAIGHT CHROMIUM STEELS	
Weldspool 405	Weldbest 410
Weldspool 410	Weldbest 430
Weldspool 420	Weldbest 442
Weldspool 430	Weldbest 446
	Weldbest 501
	Weldbest 502
LOW ALLOY STEELS	
Weldspool 70000	Weldbest 90
Weldspool 90000	Weldbest 100
Weldspool 120000	Weldbest 230
	Weldbest 260
HARD SURFACING	
	Weldbest 139 (14% Mn)
NON FERROUS ALLOYS	
Weldspool 600-Cu	Weldbest 610 SiBr
Weldspool 610-SiBr	Weldbest 620C PBr
Weldspool 620-PBr	Weldbest 730 CuNi
Weldspool 630-AlBr	Weldbest 760 Cast Iron
Weldspool 730-CuNi	Weldbest 770 Nomel
Weldspool 770 Nomel	Weldbest 780 Niconel
Weldspool 780 Niconel	Weldbest 790 Nickel
Weldspool 790 Nickel	

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ELECTRODES: Lime DC—Titania AC-DC—LIME AC-DC

ALSO MANUFACTURERS OF:
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WELDBEST DEEPWELD: DEEP PENETRATING CARBON STEEL ELECTRODE

Send for Technical Literature

WELDWIRE COMPANY, INC.
N. W. Cor. Emerald & Hagert Sts.
Philadelphia 25, Pa.
Phone: Garfield 3-1232

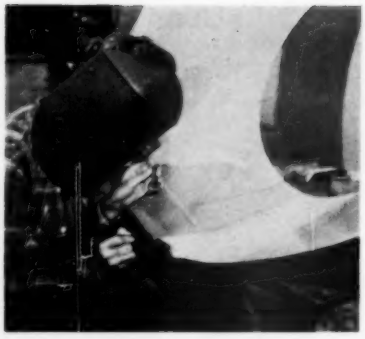


Fig. 2 Butt welds are made on an air inlet bell. This part is made of 0.093-in. thick 3-S aluminum

this plant are fabricated by Heliarc welding. This process is used for the many types and thicknesses of metals that are needed. Top-quality welds are made on aluminum, stainless steels, magnesium, titanium, Timken high-temperature alloys, Haynes Stellite alloys and other metals. Women with no previous welding experience quickly learn to use Heliarc torches on this wide range of metals.

The women at Twigg Industries like the Heliarc HW-9 welding torch. And no wonder—it weighs only 3 oz. Welding operators can use it all day long without tiring. The size and flexibility of the HW-9 also makes an easy job of welding joints that are not accessible to larger torches.

Preventing Skidding

Hope that the high national toll of human lives resulting from the skidding of automobiles on the growing number of steel deck bridges can be greatly reduced stems from a recent development by the State of Illinois Highway Department.

Accidents of this type occur most frequently during the fall and winter, when vapor rising from the water below freezes on the smooth steel grid decks.

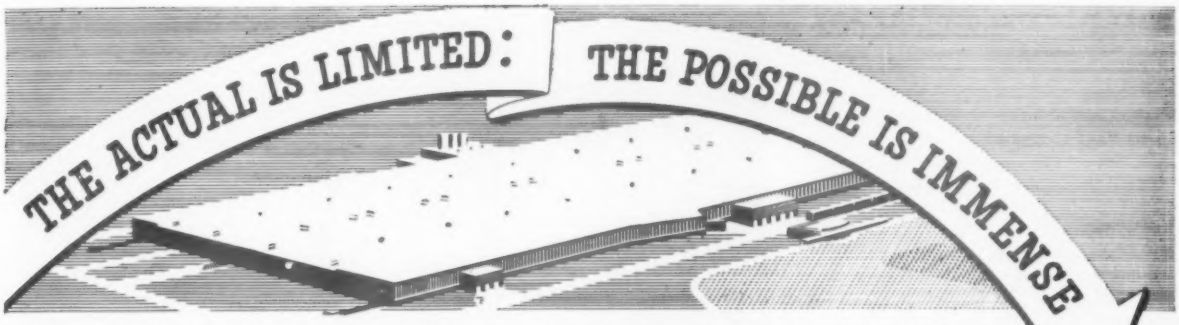
Illinois Highway Department engineers have come up with the first practical method of overcoming the icing problem by using black top over steel mesh which was secured to the grid by studs installed with the Nelson stud welding gun. The 1000-ft bridge over the Rock River at Grand Detour, Ill., 6 miles north of Dixon, was completely resurfaced in nine working days, during which time at least one-half the bridge was always open to traffic. Fourteen days had been allotted to the project.

Approximately 25,000 $^1/_4$- x 1-in. annealed no-thread studs were end welded to the steel grid on 12-in. centers, after which heavy diamond steel mesh was impaled over the studs which were then bent over to hold the mesh securely in place. Motorists, themselves, helped in the paving job as sections, where the mesh was already in place, were opened to traffic briefly, so that the weight of tires passing over the mesh would imbed it in the steel grid.

A rough coating of coarse I-11 black top was then placed on the mesh and finally a finish coat.

Studs were end welded to the grids at the rate of 7000 a day with four stud welding guns which were operated from two portable Nelson battery-operated power sources.

The resurfacing of this 1000-ft long open steel grid bridge deck at Grand Detour, Illinois, with a black top pavement was aided by motorists who were permitted to drive over the heavy diamond steel mesh on the right as a means of imbedding it in the steel grid to which it was secured with Nelson end-welded studs



NEW LINCOLN PLANT CREATED BY INCENTIVE-INSPIRED CO-ACTION IN DEVELOPING POSSIBILITIES IN PRODUCT

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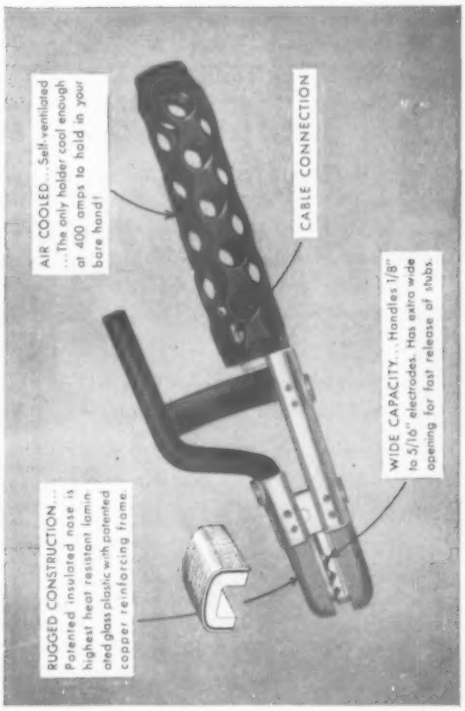
WELDS COOLER...HANDLES EASIER...SELLS FOR LESS!

LINCOLN "COOLTONG"...the self-ventilated insulated holder

- **Long Life** Copper-reinforced-with-steel design outlasts holders of like capacity.
- **Perfectly Balanced** Feels lighter, more comfortable for easier welding in any position.
- **LOW PRICED** Has more range . . . yet sells for less than insulated holders of like capacity.


AIR COOLED...Self-ventilated ...The only holder cool enough at 400 amps to hold in your bare hand!
CABLE CONNECTION
WIDE CAPACITY...Handles 1/8" to 5/16" electrodes. Has extra wide opening for fast release of stubs.
RUGGED CONSTRUCTION... Patented insulated nose is highest heat resistant laminated glass plastic with patented copper reinforcing frame.

MAKE THIS TEST!

Set Welder at 400 amps and weld with the bare hand. "COOLTONG'S" unique self-ventilated design keeps the handle from getting too hot to hold with the bare hand. *Actually runs cooler than the cable!*

TOP VALUE

GET THE FACTS NOW—Write for Bulletin 845, Dept. 1902

THE LINCOLN ELECTRIC COMPANY

Cleveland 17, Ohio

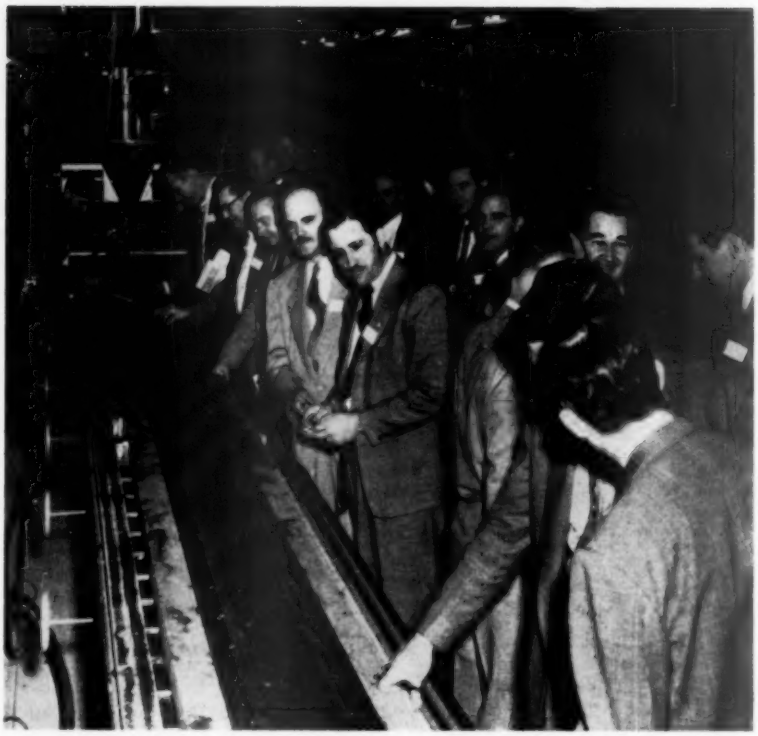
THE WORLD'S LARGEST MANUFACTURER OF ARC WELDING EQUIPMENT

Sight Feed Host to Distributors and Customers

Business and industrial leaders from Maine to California were guests of the Sight Feed Generator Co., West Alexandria, Ohio, when the firm held "Open House" throughout January for its welding electrode distributors and customers.

The occasion was the unveiling of a new Sight Feed welding product, Rexarc Automatic Welders and Positioners, for use in fabrication plants and for repair of dozens of types of equipment by the electric welding process. The new equipment became an addition to the Sight Feed line through acquisition of the Dean Weld Machine Co., Oakland, Calif., which will now operate as a subsidiary unit. Carl F. Smith, Sight Feed President, will serve as Chairman of the Board and Managing Director for the West Coast factory and will be in direct charge of production and engineering.

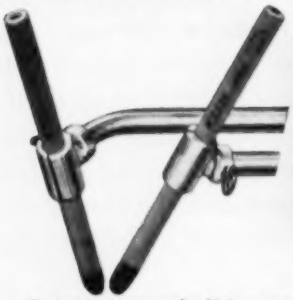
The Rexarc Automatic Welder is designed to replace by automatic procedure large numbers of welding operations previously done by hand. Company officials say the new equipment produces better quality weldments, as well as saving manufacturers and repair shops many hours of labor and considerable quantities of material. Demonstrations of the machine were made during the time the guests visited the factory.



Outstanding features of the new equipment include: provision for both low- and high-voltage welding; high-frequency starting and stabilization, assuring a

BECKER

KEEN-ARC CARBONS



FOR CONSISTENTLY GOOD RESULTS

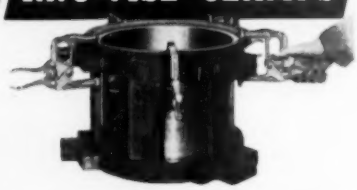
Designed to carry the high currents necessary for intense heat, BBB Keen-Arc Carbons produce a fine-grained weld of high tensile strength. They give a smooth, steady "flowing" flame which does not wander and which is concentrated at the desired focal point. Flame temperature is easily and accurately adjusted by merely changing the ampere input, and heavy copper coating permits gripping at extreme ends—eliminates frequent and periodic resetting.

A COMPLETE LINE OF CARBON WELDING SUPPLIES including carbon and graphite electrodes, carbon rods and plates, welding paste, etc. Write for catalog.

BECKER BROTHERS CARBON CO.

3450 South 52nd Ave. Cicero 50, Illinois

4 times as many cylinders now welded by using KNU-VISE CLAMPS



These *KNU-VISE* pre-set clamps* permit job to be set up now in one quarter the time—thus converting this saving of time into increased production.

Each set-up consists of clamping a ring to top of aluminum cylinder preparatory to welding.

Besides achieving faster set-up, the *KNU-VISE* clamps present no interference to the welding operation as do old style clamps which had to stick up above the work to accomplish the clamping with greatest speed.

Send for our complete catalog

*PHOTOS, COURTESY CADILLAC WELDING CO., DETROIT, MICH.

KNU-VISE PRODUCTS LAPEER MFG. CO.

3066 DAVISON ROAD • LAPEER, MICHIGAN

WESTERN DIVISION: 422 MAGNOLIA STREET • GLENDALE CALIFORNIA

the Only New DEVELOPMENT IN D. C. WELDING IN THE PAST 25 years

The complete story on the MILLER SELENIUM RECTIFIER TYPE D. C. WELDERS will prove that they are the only new development in D. C. welding in the past 25 years. We will gladly send you the complete story upon request, and why you can't dispute these facts:

★ . . . that the magnetic amplifier principle built into the MILLER SELENIUM RECTIFIER TYPE D. C. WELDER provides high current densities on the electrodes, thus causing rapid vaporization of the weld metal. This permits instantaneous voltage recovery, eliminating momentary short circuits, commonly caused by globules of metal transferred from electrodes to work.

★ . . . that vertical and overhead welding can be accomplished with greater ease by using a MILLER SR WELDER.

★ . . . that the MILLER SR WELDER will lay down a higher quality of weld metal than any other D. C. welder known today.

5
MODELS TO MEET YOUR SPECIFICATIONS

miller ELECTRIC MANUFACTURING CO.

Since 1929 — *Appleton, Wisconsin*

steady are at all times; control over low-arc voltage and amperage, which minimizes stress and dilution of parent metal. Welding can be lineal or cross-bead on flat or circular shapes, continuous or in sequence. Removable head is transferable from one positioner to another.

Welding on shafts, rollers, sheavers, idlers and similar circular surfaces is simple since rotating spindle is vertically adjustable to accommodate a large range of work sizes. Angular positioning for welding idler and roller flanges, crusher mandrils and similar applications is accomplished by hydraulically controlled elevating device. For welding on long circular work, supporting trunnions equipped with friction-bearing rolls are available.

Literature describing Sight Feed's new welders and positioners is available through its welding supply distributors or by writing directly to the company.

Nash 1953 Models

Nash Motors has announced its new 1953 Ambassador and Statesman models, featuring original continental styling and numerous mechanical advancements.

All 1953 Nash models feature Nash-pioneered "Airflyte" unitized body construction, used in modern trains and planes. Body-to-frame bolts are eliminated as the integrated body and frame are welded together to form a single unit, said by Nash engineers to be stronger and more rigid. Airflyte construction substantially eliminates useless body weight, contributing to exceptional fuel and operating economy of Nash cars.

Welding Statistics

The magazine *Steel* has just published its Annual Metalworking Yearbook, Jan. 5, 1953, containing excellent Editorials, forecasts for the coming year and statistical data. We reproduce herewith information relating to arc-welding sets and welding electrodes.

Arc Welding Sets

Units Ordered, Excluding Exports

	Single Operator, Variable Voltage, DC Sets			Transformer Welders	
	Motor Drive	Engine Drive	Generators Only	Industrial Type	Limited Input Type
1952					
Jan. ..	1,548	1,119	7	1,362	1,496
Feb. ..	1,517	933	28	1,471	1,923
Mar. ..	1,569	784	40	1,642	1,899
Apr. ..	1,329	1,277	21	1,476	1,941
May ..	1,872	1,025	5	1,596	2,027
June ..	1,401	975	13	1,438	1,518
July ..	1,182	847	33	1,233	1,235
Aug. ..	2,157	811	24	1,434	1,353
Sept. .	1,585	761	28	1,535	1,374
Oct. ..	....	....	....	....	....
Nov. ..	....	....	....	....	....
Dec. ..	....	....	....	....	....
1951	13,048	10,333	485	15,645	16,954
Jan. ..	968	837	170	1,256	1,415
Feb. ..	1,125	749	12	1,494	1,367
Mar. ..	1,269	994	47	1,634	1,362
Apr. ..	1,023	757	16	1,338	1,555
May ..	1,181	880	16	884	1,637
June ..	1,397	896	168	1,207	1,509
July ..	1,239	1,846	13	1,084	1,071
Aug. ..	579	473	10	1,306	1,083
Sept. .	1,168	617	4	1,371	1,098
Oct. ..	1,096	717	4	1,533	1,875
Nov. ..	1,059	751	11	1,514	1,825
Dec. ..	944	816	14	1,024	1,177
1950	10,115	8,207	272	9,652	16,674
1949	7,393	6,193	256	7,295	12,647
1948	10,927	10,435	385	8,792	13,690
1947	13,677	10,822	1,169	9,719	13,034
1946	16,467	10,622	2,818	21,093	16,949
1945	20,716	8,776	2,795		21,448
1944	30,230	6,023	3,140		15,426
1943	30,437	4,747	2,068		4,439
1942	60,264	5,051	2,674		8,236
1941	35,858	4,412	1,415		4,217
1940	13,646	2,649	1,168		2,478
1939	7,242	1,525	995		.....

National Electrical Manufacturers Association

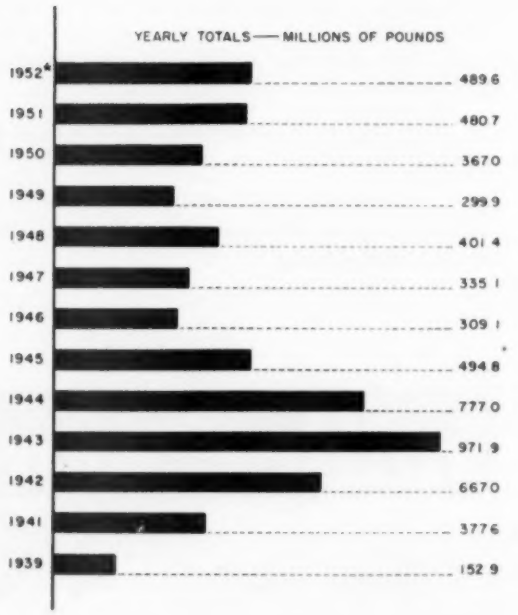
WELDING ELECTRODES

Shipments in Pounds

	Mild Steel	Alloy	Nonferrous	Total
1952				
10 Mos..	338,453,422	65,604,730	1,157,692	405,215,844
Jan. ...	34,627,235	6,999,979	140,678	41,767,892
Feb. ...	34,930,851	6,769,708	90,806	41,791,365
Mar. ...	41,837,669	6,476,757	77,230	48,391,656
Apr. ...	40,277,856	6,962,554	75,809	47,316,219
May ...	37,093,046	7,668,145	144,667	44,905,858
June ...	32,152,266	7,600,762	149,297	39,902,325
July ...	11,596,090	3,636,134	155,851	15,388,075
Aug. ...	21,223,963	4,766,026	159,187	26,149,176
Sept. ..	38,142,142	5,828,412	67,027	44,037,581
Oct. ...	46,572,304	8,896,253	97,140	55,565,697
Nov. ...	.....	.....	.....	.....
Dec. ...	.....	.....	.....	.....
1952*	.....	.....	.....	489,600,000
1951	413,444,913	65,903,970	1,361,836	480,710,719
1950	322,954,832	42,574,710	1,861,686	367,391,228
1949	273,463,740	24,753,807	1,715,362	299,932,909
1948	369,019,831	30,214,928	2,124,496	401,359,255
1947	307,756,495	25,172,382	2,149,768	335,078,645
1946	284,126,356	24,991,206†	.....	309,117,564
1945	435,789,217	59,029,935†	.....	494,819,155
1944	707,756,964	69,236,137†	.....	776,993,101
1943	.....	.....	.....	971,979,782
1942	.....	.....	.....	666,965,595
1941	.....	.....	.....	377,564,483
1939	.....	.....	.....	152,863,373

† Includes both alloy and nonferrous electrodes. * Estimated.

National Electrical Manufacturers Association



The new plastic "707" Safety Goggle combines

Protection — Comfort — Appearance

PROTECTION—is still the basic purpose of this new style goggle. Its acetate frame has been designed to retain the safety lens even when subjected to severe impact. In addition to its general use throughout industry where eye hazards are encountered, the non-sparking "707" is especially suitable for use in chemical and electrical plants.

MODEL 707 PLASTIC FRAME SPECTACLE TYPE SAFETY GOGGLE

COMFORT—Wire core temples with cable wound ends permit easy adjustment for a snug, comfortable fit. This light weight goggle with large wide flaring nose pads receives the utmost in worker approval.

APPEARANCE—Flesh tint, high line temple, keyhole bridge and drop-eye shape combine for a distinctly personal look.

The "707" is available with flat, 1.25 or 6.00 curve, heat treated safety lenses.

Order Direct and Save!

PENNSYLVANIA OPTICAL COMPANY

READING, PENNSYLVANIA

Known for Fine Ophthalmic Products Since 1886

PERSONNEL

Milton Male Made Manager

The appointment of Milton Male as manager of the building and construction industries section of U. S. Steel's commercial department has been announced by Robert C. Myers, director-market development. Mr. Male has been director of housing research in the company's research and technology division since 1946.

A native of New York City, he joined U. S. Steel in 1930 after graduating from the Massachusetts Institute of Technology with a B.S. degree in architectural engineering. Since that time Mr. Male has served in various research capacities. His new assignment will include responsibility for coordinating and assisting the technical activities of U. S. Steel's housing subsidiary, Gunnison Homes, Inc.

Mr. Male is a longtime member of the AMERICAN WELDING SOCIETY. One of his first tasks on graduating was in analysis of structural research data carried out by the American Bureau of Welding. For many years Mr. Male was an active member of the Welding Journal Committee.

Rutherford Made Chief Metallurgist

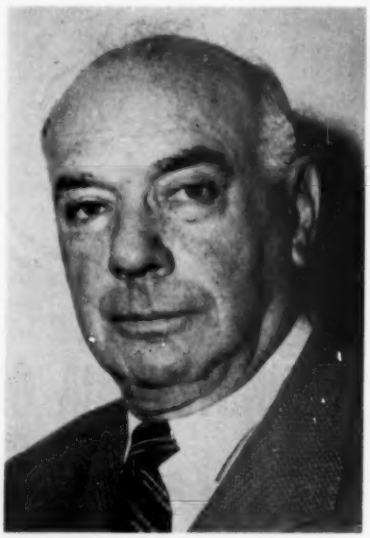
The appointment of Harold D. Newell as consulting metallurgist and John J. B. Rutherford as chief metallurgist of the Tubular Products Division of The Babcock & Wilcox Co. has been announced here by Luke E. Sawyer, vice-president.

Mr. Newell has been chief metallurgist since 1927 and in his new post will be relieved of detail work in connection with the supervision of the research section of the laboratory in order to devote his time to specific metallurgical problems. He has been with B&W since 1919 and pioneered the development of many alloy tubing steels which have since become widely used in high-temperature high-pressure applications in the petroleum, chemical and generation fields. He is the author of numerous technical publications and is a member of the ASM, ASTM, AWS, and other technical societies.

Mr. Rutherford, who has been assistant chief metallurgist, will now be in charge of the research section of the laboratory, process and product development and customer metallurgical service. Prior to his association with The Babcock & Wilcox Co. in 1938, Mr. Rutherford was a metallurgist with American Chain & Cable Co. and U. S. Steel Corp. Since coming with B&W he has been active in the development of tubular materials for the oil, chemical, boiler and automotive industries. Mr. Rutherford was born in Hamilton, Scotland and attended Heriot-Watt College in Edinburgh and is a member and active in the work of the ASME, AIME, ASM, API, ASTM, AISI, AWS and a number of other American and British technical societies.

H. C. Price Joins Bache

Harold C. Price, president of Harold C. Price Co., has been admitted to limited partnership in Bache & Co., members of the New York Stock Exchange and other leading stock and commodity exchanges.



Mr. Price, who resides in Bartlesville, is a graduate of Colorado School of Mines. He is a member of the American Petroleum Institute, American Gas Assn., American Institute of Mining & Metallurgical Engineers and the AMERICAN WELDING SOCIETY.

He is also a member of the Hillcrest Country Club, Southern Hills Country Club, the Tulsa Club and the Petroleum Club, all of Tulsa, and of the Masons, the Shriners and the American Legion in Bartlesville.

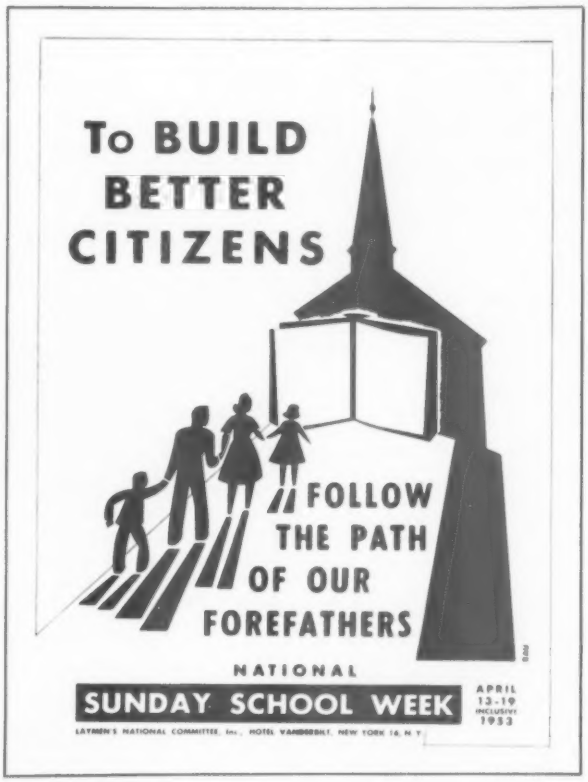
Maladra Promoted

Anthony Maladra has recently been appointed Assistant Sales Manager at KSM Products, Inc., Merchantville, N. J., manufacturers of studs and equipment for electric-arc stud welding. Mr. Maladra, an engineering graduate of Purdue University, was with Shakeproof in the Midwest before coming to KSM some time ago.

This appointment is another step in KSM's expansion program that started with the construction of a completely new plant in Merchantville which the company now occupies. Recently, KSM announced the opening of a new district office in Milwaukee to enlarge the scope of its sales and engineering service in that area.

Give your children an example of faith and courage on which to build their lives

To produce good citizens, religion must again become both a restraining and a helpful influence in the lives of our children.


To BUILD BETTER CITIZENS
FOLLOW THE PATH OF OUR FOREFATHERS
NATIONAL
SUNDAY SCHOOL WEEK
APRIL 13-19 INCLUSIVE 1953
LAYMEN'S NATIONAL COMMITTEE, Inc., HOTEL VANDERBILT, NEW YORK 16, N. Y.

SUNDAY SCHOOLS BUILD BETTER CITIZENS

By sponsoring a National Sunday School Week program in your town, community, club, school or church, more of your young people will receive religious education.

Won't you add your support to the growing number of industrial, labor and civic leaders who endorse this splendid non-sectarian work?

This advertisement is sponsored by

RENE D. WASSERMAN,

President, EUTECTIC WELDING ALLOYS CORPORATION, 172nd Street, Northern Boulevard, Flushing New York, New York.

National Sunday School Week is sponsored by:

The Laymen's National Committee • 4 Park Avenue, New York 16, N. Y.

A NON-SECTARIAN, NON-PROFIT ORGANIZATION

NEW PRODUCTS

All-Plastic Safety Goggle

The Pennsylvania Optical Co. announces the addition of its new plastic frame spectacle type safety goggle, known as Model "707," to its growing line of head and eye protective equipment.

Protection is still the basic purpose of this new goggle. Its acetate frame has been designed to retain the safety lens even when subjected to severe impact. In addition to its general use throughout industry, the nonsparking "707" is especially suitable for use in chemical and electrical plants.

The sturdy wire core temples have cable-wound ends which permit easy adjustment for a snug comfortable fit. Added comfort is found in the large wide flaring nose pads. Flesh tint, high line temples, key-hole bridge and drop-eye shape combine for a distinctly personal look.

The "707" is available with flat, 1.25 or 6.00 curve, heat treated safety lenses.

The "707" will be sold by the manufacturer direct to the industrial user, as are their other products, at a substantial saving.

Flux for Silver Brazing

An improved, all-purpose version of its "1200" flux compound for use in silver brazing operations is announced by The American Platinum Works, Newark 5, N. J.

The product, which retains the same "1200" brand name, is designed for universal application with silver solders in the brazing of ferrous and nonferrous metals. Noting that it possesses superior cleansing and protective properties, APW also emphasizes that it may be used on all metals "at all temperatures common to silver brazing."

Consisting of a mixture of fluoride and borate salts, the flux melts at a temperature lower than the alloys employed and forms a coating of fused salts over the brazing area. It performs three functions: covers the work and the brazing alloy, preventing oxidation of the surface during heating, brazing and cooling; cleans and floats off dirt or oxides; and reduces surface tension of the molten alloy, causing it to flow freely over work surfaces that have been heated to brazing temperature. A smooth paste, it is easily removed after brazing by washing with water, the firm states.

The American Platinum Works is making the "1200" flux available in 1/2-, 1- and 5-lb jars, 30-lb containers and 65-lb pails.

Hard-Facing Alloy

Superior resistance to abrasion at high temperatures, the ability to withstand attack by molten copper and improved welding characteristics are some of the important advantages offered by CM-119, a new hard-facing alloy manufactured by Coast Metals, Inc., of Little Ferry, N. J.

Because of its ability to resist abrasion at the temperature of hot-rolled steel, CM-119 has already found successful application as hard facing for large guide rolls and as hot friction guides and soaking tong bits. And its resistance to attack by molten copper permits CM-119 to yield excellent results as protection for the lips of copper converters.

CM-119 can be applied with any good arc-welding process. It has easy welding characteristics that assure efficient bonding. It will weld over itself and more ferrous materials without cracking, checking or porosity—a fact which permits patching where previously full replacement has been necessary. This and the longer service life that results from superior abrasion resistance make CM-119 exceedingly economical both for initial hard facing and subsequent rebuilding.

Work Positioner

A new electrically turned, variable speed, work positioner has just been announced by All-State Welding Alloys Co., Inc. It is offered both as a bench model and as a pedestal model and with accessories to make it inclinable and operable intermittently.

The work positioner is easily portable. Without the pedestal the complete unit weighs 31 lb, is 5 1/2 in. high and covers an area 20 x 18 in. The turntable is 15 1/2 in. in diameter. It safely carries a work load of 300 lb and moves it continuously or intermittently at speeds adjustable upward from 1/4 rpm. Electrical requirements are less than for a small light bulb. The unit feeds off any 110-v, 60-cycle plug.

Listed as the All-State "Unique" Work Positioner, the device is said to be widely applicable in many kinds of factory work, particularly in welding, brazing, soldering, tinning, cutting and metallizing. These and other assembly operations in scores of "light" industries can be cost-reduced by moving the work automatically to the position most favorable to efficient accomplishment. On other work such as surface coating, quite important cost savings are overshadowed by even more desired product improvement stemming from uniform, uninterrupted movement of the work.

Inquiries should be directed to All-State Welding Alloys Co., Inc., 249 Ferris Ave., White Plains, N. Y.

300-Amp A-C Welder

A redesigned 300-amp a-c welding transformer, featuring stepless current selection from 40 to 375 amp, has been announced by the General Electric Co.'s Welding Department.

The new welder, for practically all applications from light-duty, low-current sheet metal work to heavier-duty, high-current industrial jobs, incorporates an enlarged scale and finely threaded screw adjustment to facilitate easy current selections. It accommodates electrodes from 3/32 to 1/4 in. diameter, and has a handy range switch which enables the operator to change quickly from high to low or low to high range.

NOW!

LOOK TO REXWELD HARD SURFACING ROD

IT'S BETTER THESE WAYS:

CUT WELDING TIME

1. Rexweld builds up and holds on an edge better! This means less welding time is required.

INCREASE PRODUCTION

2. Rexweld flows more readily on flat surfaces! In machine gas welding operations valve companies have reported an increase in production per shift using Rexweld.

LESS POROSITY TENDENCY

3. Rexweld has less tendency for porosity because of its smoother flowing and better wetting properties.

BETTER WEARING QUALITY

4. Tests show Rexweld has better wearing qualities.

Hundreds of satisfied users, manufacturing such products as valves, oil pump parts, mixer shafts attest to Rexweld's ability to do a better job . . . at less cost! Rexweld is available in a wide range of grades to meet all requirements. Then too, Rexweld meets Government specifications. If you use hard surfacing rod, be sure you check Rexweld . . . it'll save you time and money.

CRUCIBLE **REXWELD HARD SURFACING ROD**

53 years of Fine steelmaking

CRUCIBLE STEEL COMPANY OF AMERICA, GENERAL SALES OFFICES, OLIVER BUILDING, PITTSBURGH, PA.

Arc-stabilizing capacitors in the redesigned equipment contribute toward increased production by enabling the operator to strike and maintain an arc without popouts, G-E engineers said.

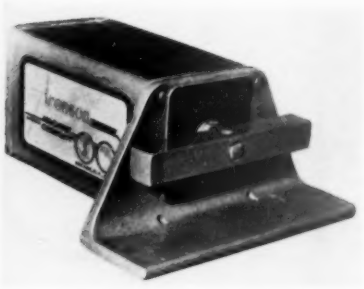
Extra protection against high temperature coil failure is provided by silicone insulation, a resin which retains its mechanical and electrical strength at high temperatures. To further protect the coils from hot spots, they are ventilated by a forced-draft fan rated for continuous duty.

The new G-E welder is built with studs at the base to simplify connecting electrode and work cables. Power-factor-correction capacitors assure low power costs. The new welder is 36 in. high, 21 in. in diameter and weighs approximately 328 lb.

Surface Indicator at Work

A General Electric portable surface resistance indicator at the Spotweld Co., Cleveland, Ohio, has "taken the guesswork out of good welding," according to one of the firm's engineers. The indicator, introduced in early 1952, provides a rapid and accurate measurement of the resistance between pieces of metal to be resistance welded. Spotweld fabricates aluminum parts for aircraft engine covers, refrigerator units for trucks, aluminum tie rails, and parts for vending machines. Using the G-E device, the company says it can check enough pieces in 15 minutes to last through a 12-hr welding period.

In operation, pieces of metal are placed between the jaws of a sample holder, desired pressure is applied and surface resistance is indicated on a microhmmeter. The entire operation is completed in a matter of seconds.

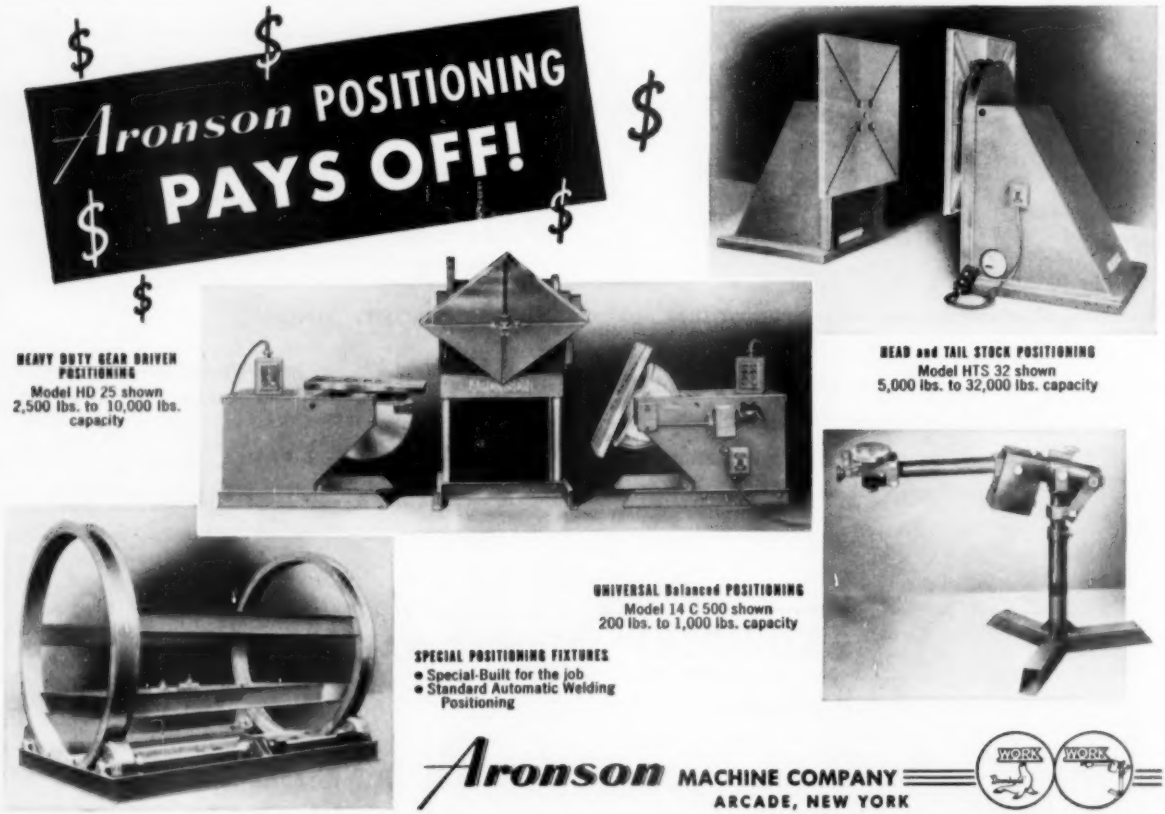


Foot Switch

Aronson Machine Co., Arcade, N. Y., manufacturers of welding positioners, announces their new model FPC Foot Power Control, a reversing foot-operated toggle switch. The switch is made up of Allen-Bradley Co.'s *Bulletin 350* Size 00 Drum Switch encased in an indestructible steel enclosure that is dust-tight and oil-tight. Operation of the switch is very simple and inadvertent operation is guarded against without detracting from the extreme ease of operation. Hand manipulation is also accomplished, as conveniently as a regular drum switch, thus providing dual-purpose control.

Assembly and disassembly is very simple. There are no parts to fail or get damaged from rough treatment. The switch is relatively small and yet has adequate space for wiring. The three-pole switch has twelve terminals and will control single-phase, two-phase, three-phase and direct-current motors. The rating is $^3/_4$-hp for ac and $^1/_3$ hp for dc motors. Action can be either nonspring return (maintained contact) or self-centering (momentary contact), changing from one to the other effected by relocation of one screw, easily accomplished in the field.

These switches were developed for welding positioner control and will prove ideal for any motor control where fast, safe, foot operation is required under conditions of rough usage.



Tobin Bronze repair of a 38,800 lb. lower base of a 1,000-ton press for stamping rear quarter automotive body panels. Base is 18½ feet long, 8¼ feet wide.

Braze-welding sends 19-ton press base back to work in 10 days

"Too tough" for other shops—but skill and Tobin Bronze Welding Rods repair 3 breaks to close tolerance

This press base broke in three pieces. On one end, side members pulled ¾ in. out of line. Since the owner insisted on .020-in. tolerance on all dimensions, the right repair shop was hard to find. That is, until Jack Sinclair, Manager, Super-Arc Welding Co. of Detroit, agreed to do this unusual job.

Thermal stresses can easily warp or crack large castings like these. To avoid this, Sinclair braze-welded with Tobin Bronze* Welding Rods. A braze weld needs less preheating. High stresses don't build up. Also, Sinclair knew from experience that Tobin Bronze would flow freely, "tin" quickly, give strong, sound bonds. Welding with Tobin Bronze proved fast, economical and dependable—and had this huge casting back on the job in ten days.

ANACONDA Welding Rods for many types of repair and production jobs are available from distributors throughout the United States. The American Brass Company, Waterbury 20, Conn. In Canada: Anaconda American Brass Ltd., New Toronto, Ont. 53156

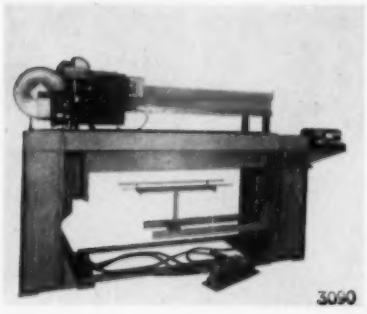
*Reg. U. S. Pat. Off.

braze or weld with confidence— ANACONDA® welding rods

ANACONDA

Welding Machine

Morton Manufacturing Co., Muskegon Heights, Mich., has developed a new design Model A Stake Welding Machine incorporating an entirely new type of clamping arrangement. It offers flat clamping with no tendency for seam separation under load. It also offers less operator interference and better visibility in the welding area.



The stake, mounted on an air-actuated vertical slide, is supported and aligned at the outer end by a manually operated shot pin. Interlocking air valves protect the machine from improper operating sequence. A manual-operated gage bar is built into the machine. High clamping pressure and other numerous features incorporated in Morton Stake Welding Machines are provided. This machine is offered in a wide range of sizes to suit specific requirements.

Flame Washing Torch

An oxy-acetylene flame washing torch for removing riser pads from castings has been developed by the National Cylinder Gas Co., Chicago. The NCG torch, according to the company, effects substantial savings of time in cleaning operations as compared to chipping and grinding.

The design of the torch is such that it produces a washing, rather than a grooving or cutting, action—leaving a smooth surface that seldom requires additional finishing. It is available with 20- or 75-deg heads, and with two sizes of tips.

Removing riser pad on casting with National Cylinder Gas Company's flame washing torch

The torch is adaptable to many other foundry cleaning-room jobs such as removal of chill bars and shallow cracks.

It requires only oxygen and acetylene gases for successful operation on steel castings. A special powder cutting version of the torch has been developed for use on stainless and high-alloy steel castings. It can be used with any type of powder-dispensing equipment.

Welder Timer Analyzer

Robotron Corp., manufacturer of Automatic Industrial Electronic Controls, announces an electronic tube analyzer for

LIL CHAMP
SAYS... "INSURE SAFE DEPOSITS — BANK ON CHAMPION Welding Electrodes"
BOY, IT'S JUST LIKE PUTTING MONEY IN THE BANK USING CHAMPION ELECTRODES!! SOUND, SAFE DEPOSITS... MORE WELD FOOTAGE!!!
BROTHER, I AGREE... THERE'S NOTHING LIKE 'EM FOR FAST WORK!
FOR TOP QUALITY WELDS CHAMPION ELECTRODES DELIVER THAT EXTRA FACTOR OF SAFETY!! THERE IS A DEPENDABLE CHAMPION ELECTRODE FOR ANY WELDING APPLICATION.
STOCK ROOM
CHAMPION
THE CHAMPION RIVET CO.
CLEVELAND, OHIO
East Chicago, Ind

Alloy Rods Co.

LOOK FOR THE FLAMING ARC TRADEMARK

ALLOY RODS COMPANY

The Leading Manufacturer of Alloy Arc Welding Electrodes

PRESENTS

THE FIRST "INSIDE STORY" FILM

OF HOW ARC WELDING ELECTRODES ARE MADE

"No Finer Electrodes Made... Anywhere"

A 22-MINUTE SOUND MOTION PICTURE IN FULL COLOR

MADE INSIDE ALLOY RODS' YORK, PENNSYLVANIA PLANT

Never before to our knowledge, since arc welding became of age as a major fabricating tool for American industry in the early 1930's, has any electrode manufacturer permitted the public to see how coated arc welding electrodes are made. The manufacturing processes and procedures have always been carefully guarded trade secrets.

Now, for the first time, *Alloy Rods Company* has filmed its entire manufacturing process in the interests of better trade relations and technical understanding . . . from the cold drawing of hot rolled rod to the packaging of its finished electrodes in moisture-proof metal containers. You can now see how arc welding electrodes are made.

"No Finer Electrodes Made . . . Anywhere" is not a sales film or promotional tool. It is technical and instructional . . . shot on the production lines and in the laboratories . . . to show those interested in better arc welding *why* we make electrodes this way. Prints of this film are available, without charge, to any reputable organization or institution.

WRITE, WIRE, OR TELEPHONE to Department M if you would like to use this film for any organizational or educational purpose. We will try to have a print available to fit your next open date.

ALLOY RODS
COMPANY
YORK, PENNSYLVANIA

NO FINER ELECTRODES MADE . . . ANYWHERE

AR-12

WESTERN PREMIERE • At the Western Metal Exposition, Pan-Pacific Auditorium, Los Angeles . . . March 23-27, 1953 . . . Alloy Rods Company Exhibit . . . Space 105 . . . Showing Every Hour on the Hour.

comprehensive check on Thyrotron Control Tubes. Described as an easily understood analyzer this little (4 x 4 x 6 in.) instrument checks on the filament continuity cathode emission, control grid characteristics and shield control characteristics as well as excessive arc drops within the tube and internal shorts.

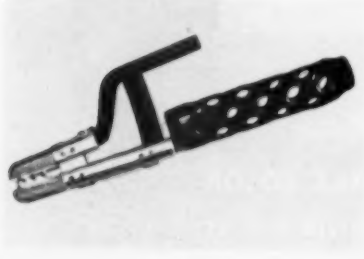
Incorporating a potentiometer knob with a self explanatory indicating dial and a neon indicating lamp, the checker simulates actual operating conditions of welder timers.

This new device gives a quick comprehensive analysis of Thyrotron Tubes 2050, 502A, 2D21 and 2051.

For further technical data write Robotron Corp., 21300 W. Eight Mile Rd., Detroit 19, Mich.

Electrode Holder

A new 400-amp insulated electrode holder, the Cooltong, has been announced by The Lincoln Electric Co. of Cleveland, Ohio. The Cooltong holder has several patented features which field tests have proved to give longer service life and cooler operation than is normal with holders of similar capacity. It is claimed that in one test made with the holder, it remained cool enough to weld with bare hands when using 400 amp current.



The nose is a special "sandwich" construction consisting of a copper core between four and six layers of laminated, glass impregnated, plastic cloth. This patented construction gives longer service life because the copper core, in addition to being reinforcement, dissipates heat so that it will not concentrate in the nose causing deterioration in the insulation.

The jaws, covered by this special insulating construction, are made of tough, highly conductive, Mallory 3 Metal, nonspatter type. They will handle electrodes from $^1/_8$ to $^5/_{16}$ in. in size and have a wide opening to permit fast release of stubs.

Current carrying frame parts are made of pure copper for high conductivity. These parts are reinforced with steel to increase the rigidity and strength of the frame. Frame insulation is covered with a copper sheathing to protect insulating part from heat and spatter and to keep the holder cooler by carrying away heat.

The holder handle is perforated with large holes to provide superventilation and reduce heating from induced currents when welding with ac. The handle is unbreakable and is easy to hold in any position.

The holder is light, perfectly balanced, completely insulated and will not break when dropped or otherwise abused. It is priced below the range normal for holders of 400 amp capacity.

Guides for Cutting Torches

Development of a complete series of new, precision-type *cutting guides* for individual gas flame metal cutting torches, such as are used by thousands of shop mechanics and field workmen in practically all branches of industry, has been announced by New Era Engineering Co., Chicago.

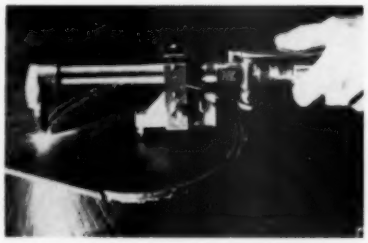


Fig. 1 Small circle cutting guide

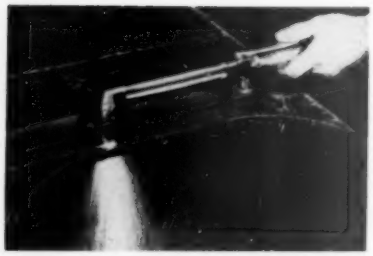


Fig. 2 Straight cutting guide

The guides are designed to provide the workman with simple, low-cost attachments that enable him to do accurate cutting—circles, straight lines, bevels and sundry shapes—with no special training or skill. As emergency or standby equipment in any shop, they provide a means for quickly producing parts that would ordinarily take days if ordered from an outside source of supply. Also, they permit marked economies when the production of only one or a few parts is required.

Made in styles to fit all makes of torches (from 70 to 90 deg models), the guides are of three principal types: a small circle guide for cutting circles from 1 to 15 in. in

Rebuild WORN TRACTOR PARTS
with . . .
PROVEN BY THOUSANDS TO LAST LONGER
MANGANAL
U.S. Patents 1,876,738—1,947,167—2,021,945
11% - 13½% Manganese-Nickel Steel
FASTER, MORE ECONOMICALLY!
✓MANGANAL SPECIAL SHAPE APPLICATOR BARS replace worn edges of tractor blade and grousers—cuts down time.
✓MANGANAL BARE ELECTRODES rebuild drive sprockets, track rollers and idlers — cost less than new parts.
✓MANGANAL FLAT APPLICATOR BARS rebuild worn corner bits — like new.
Manganal — the toughest metal known not harmed by heat.
Send for catalog and price list.
FREE
Literature on the latest methods for speedy and economical repair of worn equipment.
NEAREST DISTRIBUTOR UPON REQUEST
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SOLE PRODUCERS 92 N. J. RAILROAD AVE. NEWARK, N. J.

diameter, a large circle guide for circles 10 to 66 in. in diameter. A straight-line guide is available and can be arranged for straight and 60 or 45-deg bevel cutting. The guides can be attached to torches ready for use in 2 or 3 min time; finger-tip adjustments need no tools.

Torch and lightweight guide together are compact and completely portable. Built-in positioning fixtures are designed to hold torch tips constantly at most effective distance from the metal resulting in neater, more uniform cuts which require little or no additional grinding or machine finishing.

The guides are offered singly or in kits to handle a variety of work. Complete information can be had by writing to the manufacturer, New Era Engineering Co., Dept. G-95, 458 W. 29th St., Chicago 16, Ill.

New Spray-On Dye Penetrant Inspection

A new development is announced—a more reliable dye penetrant test to locate cracks in any solid material. A packaged kit is available, easily carried, for inspection of small questionable areas and remote located parts at any time. Features include spray can sealing of messy constituents, for cleanest and most conveniently rapid spray application to any part. Spotcheck dye penetrant test kits are sold from stock, in a specially designed, rugged carrying case.

For plant maintenance of mechanical equipment or for tool inspection in any industry, for weld, casting or forging inspection, or for overhaul tests of any transportation equipment, the Spotcheck kit is carried in one hand to the parts in question, and tests for cracks carried out in but a few minutes. No power or special lights are required.

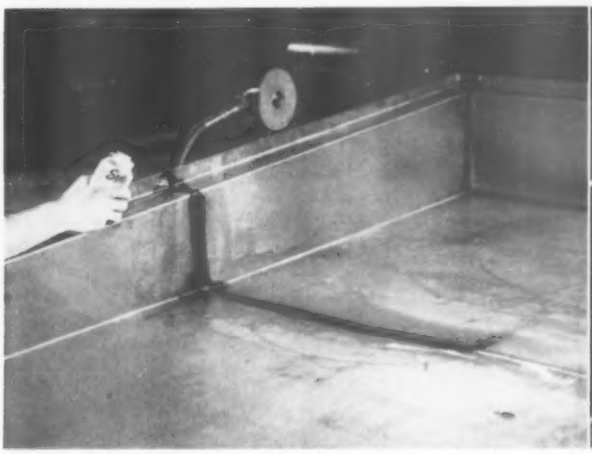
The dye penetrant is pressure-can sprayed on the clean surface to be tested. Spraying is easy and noncritical, like spraying an insect spray from a pressure can. Then a cleaner is sprayed on the surface, and removed by a quick wipe. An even coat of white developer is brushed on, and inspection follows in a few seconds. Cracks show up as bright red lines, and pores or leaks in tanks show as bright red spots.

As the Spotcheck name implies, this inspection is best and cheapest when applied to local areas of large parts, or in remote locations where only a few parts are to be tested. The test is readily used wherever a few parts are infrequently tested, as in a tool room or tool crib. This nontoxic dye penetrant test improvement is developed from Magnaflux Corp.'s 23 years of experience in nondestructive testing, and from their 10 years sale of penetrants that are fluorescent, used for volume inspection in all metal-working industries. As reliance upon nondestructive testing increases to free industries from the costs and waste of cracked parts, the new dye penetrant inspection expands these benefits and lowers the initial purchase cost for greater benefits to more companies.

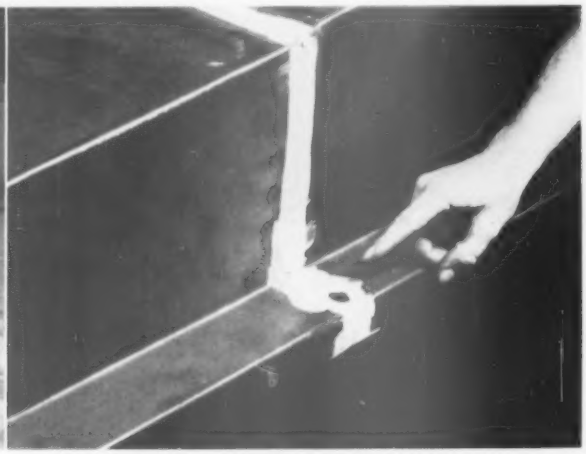
Spotcheck kits or further technical information available from: Magnaflux Corp. 5900 Northwest Highway, Chicago 31, Ill.

Helmet Shade

A new all-shade welder's helmet is being introduced under the name Vari-Shade,



Spraying Spotcheck penetrant on welded tank of complex shape, to test for leaks in weld



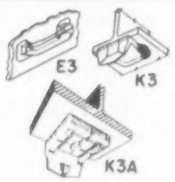
With Spotcheck on back surface of weld from penetrant, leak shows as bright red spot

UNITED STATES
TESTING COMPANY, INC.

INSPECTION and TESTING of
Welding and Weldments
QUALIFICATION of
Procedures and Operators

Main Laboratories Hoboken, N. J.

Boston - Chicago - New York - Philadelphia - Providence



WELDING CONNECTORS

Saxe Welding Connection Units position and secure structural parts to be welded.

Clip K3A permits an adjustable connection.

These widely used units eliminate all hole punching, and, with welding, produce the most economical, safe, and quickly erected structural frame.

Write for 1951 edition, Structural Welding Practice Manual.

J. H. WILLIAMS & CO.
Buffalo 7, N. Y.

AIR REDUCTION CANADA, LTD.
Montreal 2, Canada

Why You Should Use...
PAGE Automatic Welding Wire

• PAGE Automatic Welding Wire is made to rigid specifications which provide consistent characteristics for smooth flow of metal during continuous or intermittent welding. There are many analyses for a wide variety of uses.

for INERT GAS Welding

PAGE Stainless Steel Wire is precision thread-wound on 25-lb. non-returnable convenient reels which fit popular arc welding machines. Six Page-Allegheny grades; wire diameters: .035″, .045″, .0625″.

for SUBMERGED ARC Welding

PAGE stainless, low alloy, and carbon steel wire in layer-wound coils, in 22″ or 24″ mill coils, or on 200-lb. returnable steel reels. Wire diameters from 1/32″ to 5/16″; copper coated if desired.

ACCO

Write to our Monessen, Pennsylvania office for Bulletin DH-402

PAGE STEEL AND WIRE DIVISION
AMERICAN CHAIN & CABLE

Monessen, Pa., Atlanta, Chicago, Denver, Detroit, Los Angeles, New York, Philadelphia, Portland, San Francisco, Bridgeport, Conn.

PAGE Welding Electrodes AND Rods

manufactured by Polacoat Inc., 9758 Conklin Rd., Blue Ash, Ohio.

Designed to fit all standard welder's helmets, the unit gives complete protection in shades from 6 to 12. This unit eliminates the necessity of changing lenses whenever you are changing from one type of work to another. It is particularly fine

Vari-Shade Helmet

for starting and welding on close work where you want to see your work without running the risk of burns or eye damage with the hood up. After the arc is struck, a flick of the hand turns the attachment to higher intensity.

The Vari-Shade helmet attachment is furnished with a 1000-hr cover lense for the further convenience of the user.

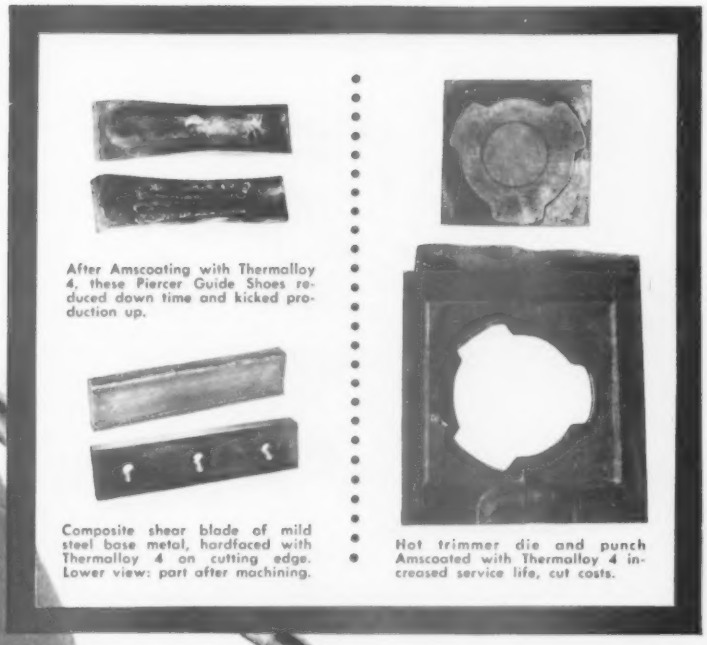
New Cast-Iron Welding Flux

A new development in a cast-iron welding flux is Johnson's Cast-Iron Welding Flux. From extensive shop experience this new flux has shown good performance on both old and new castings.

In gas welding cast iron with cast-iron rod, this reddish brown welding flux eliminates carbon from pores and floats slag away. Rod metal flows easily and smoothly into the casting and as the flux melts and flows it protects the welding surface from overheating and assures solid, sound joints.

Johnson's Cast-Iron Welding Flux will not deteriorate when not in use.

The flux is packaged in 1-lb cans and welders can get a free trial supply of this flux by writing to Johnson Manufacturing Co., Inc., Mount Vernon, Iowa.



After Amscoating with Thermalloy 4, these Piercer Guide Shoes reduced down time and kicked production up.

Composite shear blade of mild steel base metal, hardfaced with Thermalloy 4 on cutting edge. Lower view: part after machining.

Hot trimmer die and punch Amscoated with Thermalloy 4 increased service life, cut costs.

BEAT HEAT WEAR and IMPACT with AMSCO THERMALLOY 4

If you have a wear problem involving high temperatures and requiring resistance to impact, this new Amsco hardfacing electrode can save you time and money

Elevated temperatures are tough to cope with in situations involving thermal shock, metal-to-metal wear, hot gas corrosion, high temperature oxidation—especially when you need great impact resistance. Here's where Amsco Thermalloy 4 can step in and give you longer service life, and big savings in time and money.

Supplied as both a composite coated electrode for electric welding or as a bare cast rod for gas welding, both types deposit a high-carbon stainless alloy containing chromium and nickel as the principle alloying elements. In many applications, it can replace expensive nickel base alloy materials. Thermalloy 4 is packaged in 50-lb. boxes or in 10-lb. packages in 50-lb. boxes. For detailed analyses and other pertinent information, write for catalog sheet on Thermalloy 4 or contact your nearest Amsco distributor.

AMSCOATING

THE RIGHT WAY TO SAY HARDFACING

AMERICAN Brake Shoe COMPANY

AMERICAN MANGANESE STEEL DIVISION

399 EAST 14th STREET • CHICAGO HEIGHTS, ILL.

Other Plants: New Castle, Del., Denver, Oakland, Cal., Los Angeles, St. Louis. In Canada: Joliette Steel Division, Joliette, Que.
Amsco Welding Products distributed in Canada by Canadian Liquid Air Co., Ltd.

8,428* MEN OF WELDING

*AMERICAN WELDING SOCIETY MEMBERSHIP NOVEMBER 30, 1952

support A.W.S. activities

Since 1919, the American Welding Society has exerted a constant influence for the betterment of welding processes through research and exchanges of experience within its membership. Many of the 8,428 men in A.W.S. are leaders in their respective industries today because of training and encouragement they have received from other "Men of Welding" in the Society.

A.W.S. builds "Men of Welding"

YOUR COMPANY CAN PARTICIPATE THROUGH A SUSTAINING OR SUPPORTING MEMBERSHIP. GET THE FACTS ABOUT A.W.S.

There are 66 active local sections of A.W.S. covering almost every part of the United States. They hold monthly technical meetings and plant visitations. They bring together the best welding minds of the nation and present accurate information on Welding design, fabrication and maintenance. You will profit from A.W.S. membership.

AMERICAN WELDING SOCIETY
33 W. 39th St. New York 18, N. Y.

Please send me more information on advantages of membership in the American Welding Society

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*MEN OF WELDING" ADVANCE IN THEIR PROFESSION THROUGH TECHNICAL MEETINGS AND GROUP DISCUSSIONS ON WELDING METHODS AND PRACTICES.

American Welding Society

A POWERFUL FORCE IN WELDING PROGRESS SINCE 1919

33 WEST 39TH ST. • NEW YORK 18, N. Y.

NEW LITERATURE

Power Supply for Resistance Welding Machines

A pamphlet, WELDING JOURNAL size, of 59 pages has been prepared by the AIEE Subcommittee on Power Supply for Resistance Welding Machines. Recognizing that the installation and use of any resistance-welding process vitally concerns not only the industrialist requiring the process but also the welding machine manufacturer and the utility supplying the electric power as well, the committee has in this report brought together much pertinent data from the knowledge, literature and experience in all these fields.

Arrangements have been made for distribution of this report to members of the AMERICAN WELDING SOCIETY at the regular price of one dollar. Orders should be addressed to F. J. Mooney, Assistant Secretary, AMERICAN WELDING SOCIETY, 33 W. 39th St., New York 18, N. Y.

Metal Working Bulletin

Linde Air Products Co., 30 E. 42nd St., New York 17, N. Y., has issued an 8-page bulletin describing their new flame-plating processes and some applications of Heliarc and sigma welding.

Welded Tank Cars

The American Car and Foundry Co., 30 Church St., New York 8, N. Y., has issued an attractive brochure of 24 pages giving complete information on their large variety of tank cars which are for the most part all-welded. This brochure describes some of the detailed operations.

Stainless Surface Finishing Chart

Third in a series of wall charts covering fabricating and finishing of stainless steel is being issued by distributors of Armco Steel Corp. in various principal cities.

The latest 25- x 38-in. two-color chart pictures and describes the principal steps in weld bead finishing, and includes a series of photographs on how to get the best results in surface finishing. Also included is a handy table listing the sequence of operations and recommendations for wheel speeds, abrasives and lubricants for grinding and polishing stainless steels.

The chart can be obtained free from the nearest Armco Stainless distributor, or by writing to the company in Middletown, Ohio.

Hard Facing

A new 4-page, two-color illustrated folder (Form 102) describing properties, application methods and typical uses of Colmonoy No. 1 hard-facing welding rod is now available from Wall-Colmonoy Corp., 19345 John R St., Detroit 3, Mich. Number 1 hard-facing metal resists extreme impact and abrasion, has a 58 to 63 Rockwell C hardness and is available in 1/8-, 3/16- and 1/4-in. yellow tipped electrodes.

Included in the folder are line drawings showing application methods in addition to illustrations of oil refinery catalyst slide valves and stone mill hammers that have been wearproofed with No. 1 Alloy. Forty-eight typical parts which have been hard faced with the No. 1 Alloy by a broad range of industries are listed.

Steel Castings Handbook

Unprecedented demand for the *Steel Castings Handbook*, official manual of the steel castings industry, has necessitated a second printing of the new, enlarged and completely revised volume compiled and published by Steel Founders' Society of America.

Widely recognized by engineers, libraries and university faculties as the official source of authoritative information on cast steel products and processes, the comprehensive handbook is considered unique in the completeness of its general data on steel castings, specifications, applications, design principles, mechanical and physical properties, and related technical materials. Both the standard and special low-cost student editions will continue to be available.

The completely revised volume, first published late in 1950 to supplant the original edition, incorporated 520 pages of text, 440 illustrations and 120 essential tables. It includes 16 definitive chapters covering the entire range of steel castings activities, a brief history and much specific data of value to engineers, designers, production executives, students and others active in the metals working field.

Copies may be obtained from F. Kermit Donaldson, Executive Vice-President, Steel Founders' Society of America, 920 Midland Building, Cleveland 15, Ohio. Price of the standard edition is $4.00; student copies are available at $1.50 each.

. . . an all-position phosphor-bronze electrode that's easy to handle.

Phos-Trode is ideally suited for overlay work and for general maintenance and repair welding throughout industry.

In addition you get these 4 important advantages that keep welding costs down.

1. **All position** — Deposit solidifies rapidly — can be used for flat, vertical or overhead welding, operates on reverse polarity DC.

2. **Welds dissimilar metals**— cast iron, bronze, brass, copper, galvanized and malleable iron, etc. and combinations of same. This versatility keeps welding costs down and simplifies your electrode stocking problems.

3. **High deposition rate** — Low spatter loss permits high welding currents for faster welding and lower costs.

4. **Sound deposits, high physicals** — Special ingredients in Phos-Trode coating give properly deoxidized deposits, sound welds and correct bead contour.

Phos-Trode, the most versatile electrode in the phosphor-bronze field, is available in 6 sizes from 3/32" to 1/4". Order your supply now and take advantage of Phos-Trode's 4-way savings.

W-116

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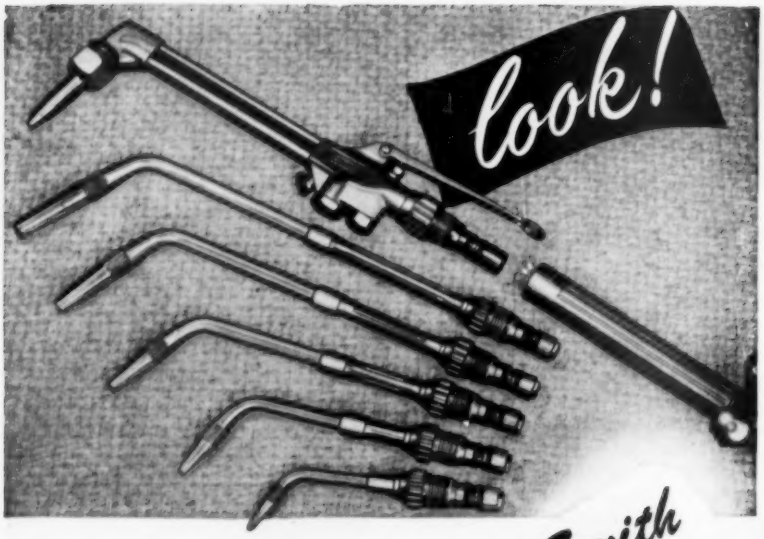
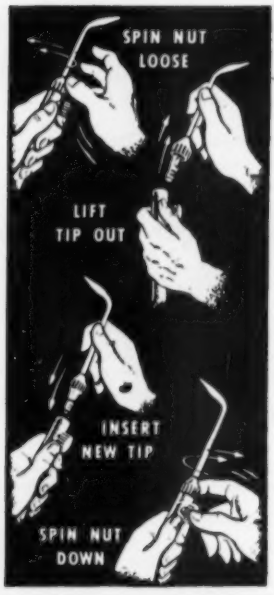
MILWAUKEE 46, WISCONSIN
West Coast Plant: Burbank, California

It's Production-Wise to Ampco-ize!



You can change these Smith 1 Tips in 6 Seconds



- No wrench necessary
- Fingers do the job
- Fast line-up of tip
- Fast change from welding to cutting

How do you like that for fast, efficient operation? No searching for wrenches—no wasted time. Just use fingers only. In actual demonstrations, operators have been able to remove and replace 4 tips in the time another operator could remove and replace 1 tip in an old fashioned model. And the seal stays tight even if tip is battered or nicked!

This is the kind of progress modern industry needs and wants. But it's not the only advantage you get with this new Smith equipment. Note that the Cutting Assembly can be attached just as quickly as a tip and the new "FLO-TROL" feature eliminates reverse flow of gas—prevents burned out seats. Keeps torch on the job . . . does away with costly delays. Another ingenious feature permits rotating the tip **while flame is burning!** (Heavy Duty Torch Body and Cutting Assembly, illustrated above, carries Lifelong Guarantee).

THAT'S ALL! . . . JUST 6 SECONDS; IT'S NEW AND REVOLUTIONARY

MAIL COUPON TODAY FOR DETAILS

SMITH WELDING EQUIPMENT CORPORATION

Manufacturers of fine Welding Equipment for over 40 Years

Smith Welding Equipment Corporation
2634 S.E. 4th, Minneapolis, Minn.

Please send me more information on the time-saving and money-saving features of your new torch.

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City_____ State_____ WS-12

Alloy Castings

"Carbon and Alloy Steel Castings," reprinted from the September 1952 issue of *Materials and Methods* is available in Bulletin form. This comprehensive article on properties, specifications, design, welding and heat treatment of steel castings may be obtained by writing to Steel Founders' Society of America, 920 Midland Building, Cleveland 15, Ohio.

Accessories Catalog

Signaling the newest expansion of service to its customers, the Welding Division of A. O. Smith Corp. of Milwaukee has just issued a welding accessories catalog which offers customers a complete line of such accessories and make ordering and shipment a vastly speeded operation.

The welding accessories line is an innovation of the past half year.

National distribution of these accessories is achieved through A. O. Smith's own distributor organization and its factory service branches at Chicago, Union, N. J. Dallas, Tex., and Oakland, Calif.

The "package buying" method offered by the new 16-page catalog is backed up by speedy shipment from stock on the same day orders are received, the division reports.

In charge of this new activity is Warren Ware, formerly of The Lincoln Electric Co., Cleveland. His title is manager of specialty sales in the Welding Division.

Fixture Clamps

The new catalog issued by Morton Machine Works, Ferndale 20, Mich., manufacturers of the MT line of Fixture Clamps and Component Parts, features Morton's new improved line of Fixture Clamps and Fixture Details which are standard and made with skilled workmanship and high-quality material, and which will save toolroom time and labor.

This informative, well-illustrated catalog may be obtained from Morton Machine Works, Department 18, 2421 Wolcott St., Ferndale 20, Mich.

NEW

Cost cutting
Hard Surfacing
Electrodes

McKAY HARDALLOY

Low Hydrogen* - Hard Surfacing

ELECTRODES

Hard Surfacing Problems?

McKay Hardalloy Electrodes are the solution to your Hard Surfacing problems. Hard Surfacing Manuals, covering your specific application, are available upon request.

This complete new line of Hard Surfacing Electrodes was developed by The McKay Company, a leader in the stainless and alloy electrode field for many years. To cut costs and save money let us help you make the proper selection of the McKay Hardalloy Electrode for your specific application.

**Packaged in hermetically sealed cans.*

THE McKAY COMPANY • 1005 LIBERTY AVE., PITTSBURGH 22, PA.

SECTION NEWS AND EVENTS

as relayed to C. M. O'Leary

Battle of the Cities

Bethlehem, Pa.—Approximately thirty-one members and guests of the *Lehigh Valley* Section were present on Jan. 5, 1953, for dinner and to hear Robert T. Arnold, of Hornblower & Weeks, Philadelphia, Pa., as the coffee speaker, and to see a film presented by him entitled "What Makes a Stock Market Tick." This was followed by a short question-and-answer period.

The main event of the meeting was the "Battle of the Cities."—A very interesting question-and-answer program with AWS members on teams from Allentown, Bethlehem and Easton competing in answering questions on welding design, metallurgy and fabrication. After a terrific battle, the Allentown team won. The team members were:

Allentown: Warren Taylor, John Perry and Fred Snyder.

Bethlehem: Henry C. VonBlohn, R. I. Fluck and Leonard Elly.

Easton: Julius Naab, Russell Smith and B. F. Shepherd.

The judges were E. L. Durkee, Cyril D. Jensen and R. A. Bartholomew; the moderator was James Fairhurst.

Floating Dry Docks

Bridgeport, Conn.—H. A. Sawyer, Jr., Associate Professor of Civil Engineering, University of Connecticut, School of Engineering, was the speaker at the monthly dinner meeting of the *Bridgeport* Section held on January 15th at Rapps Restaurant, Shelton. Mr. Sawyer covered methods, applications and processes in his excellent talk on the subject "Welding of Floating Dry Docks."

Induction Heating Applications

Chicago, Ill.—Thomas J. O'Brien AWS, Weltronic Induction Heating Corp., was the guest speaker at the regular monthly meeting of the *Chicago* Section held on January 16th in the auditorium of the Peoples Gas Light and Coke Company. Dinner was held prior to the meeting at Burke's Grill and Restaurant. Mr. O'Brien's subject "Induction Heating Applications" covered a brief history of induction heating and description of theory of basic equipment necessary to generate high frequency needed to induction heat metal parts. Applications of induction heating generator and associated handling equipment for production: hardening, brazing, soldering, hot forming, annealing were also covered. This was augmented with colored movies and slides to bring out points discussed. A film "No Finer Electrodes Made Anywhere" was also shown.

Safety in Welding Operations

Cleveland, Ohio.—The January meeting of the *Cleveland* section was held on Wednesday evening, the 14th, in the Hotel Allerton. A record turnout of 170 for dinner and approximately 200 for the technical session paid tribute to the speaker for the evening, Simon A. Greenberg, technical secretary of AWS, whose subject was "Safety in Welding Operations." The meeting was also honored by the attendance of Joseph Magrath and Frank Mooney, Secretary and Assistant Secretary of the SOCIETY.

Chairman Frank Flocke opened the meeting with introductions of the visiting SOCIETY secretaries and then called on Michael Shane, Past-Chairman and Chairman for Ladies' Night, to give in his own "special" style a run-down on the evening program for February 11th. John Rogos was also called on to make his regular report on membership. He reported the section had recruited 42 new members to date.

Howard Schell, Coffee Talker Chairman, introduced the coffee talker, Frank Gibbons, baseball writer for the Cleveland Press. Members and their guests were given an inside look at the club prospects and some of their problems for the coming season.

Following the intermission for clearing tables, Chairman Flocke opened the technical session by asking Mr. Magrath for a report. The SOCIETY'S secretaries had been in Cleveland to begin arrangements for the national fall meeting to be held in October. Mr. Magrath briefly paid tribute to those whose hard work made the SOCIETY'S meetings a success and called on the local section members to pitch into the job of preparing for the fall meeting. He mentioned briefly plans for the spring meeting in Houston.

Lew Gilbert, Program Chairman, introduced the speaker for the evening, Mr. Greenberg.

Beginning with the statement that "welding is a safe operation," Mr. Greenberg first developed the thought that if welding operations are undertaken with common sense, the operator is safer when he is welding than when driving his car. He made the point that it is an essential step in applying common sense to give some one person responsibility for safety in the plant.

Mr. Greenberg also discussed briefly the following safety suggestions:

Most regular production welding operations are set up for safe welding. Extra caution is needed, however, when maintenance welding or other welding outside of regular production is done. The safety engineer or person responsible should check such welding setups. Production welding setups should also be checked regularly for safety, and the welding operator should not touch equipment other than to make normal operating adjustments. Only qualified electricians or maintenance men should make changes or repairs.

For safety recommendations the reference with which all plants should be familiar is the American Standard Z49-Safety in Electric and Gas Welding and Cutting Operations. It is available through the SOCIETY'S offices. Mr. Greenberg made detailed reference to Section 8 of Z49 in discussing ventilation. He outlined safety precautions when welding in confined spaces, with fluoride bearing fluxes and with stainless electrodes. The latter electrodes he indicated were entirely safe when normal ventilation is provided.

Brief mention was made of the study now under progress of inert-arc safety requirements. No recommendations have been made as yet. A report is available on the study made by the atomic energy commission on the use of thoriated tungsten electrodes. The thoriated electrodes have been found to be completely safe.

Mr. Greenberg closed with a passing mention of some of the false notions about welding. He stated that there has been no substantiation whatsoever of the claims that welders are prone to tuberculosis and pneumonia or that they are in danger of sterility. Another misconception he said was not true is the claim that a-c shock is worse than d-c shock. Shock from either type of current is equally bad.

Costs

Columbus, Ohio.—A joint meeting of the AWS *Columbus* Section and ASME was held on January 9th at the Faculty Club of the Ohio State University with an attendance of 110 at dinner and 130 at the technical meeting. Leslie S. McPhee AWS of the Whiting Corp. gave his common sense approach to cost control. His

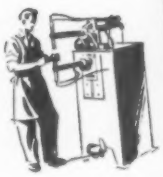
Magnetic? OR Electronic? WELDER CONTROL — WHICH WILL DO YOUR JOB BEST?

Square D makes them all . . . for simplest or most exacting applications!

Magnetic

for General Purpose Machines

For applications requiring widely varying welding conditions, normal welding speeds and maximum simplicity.

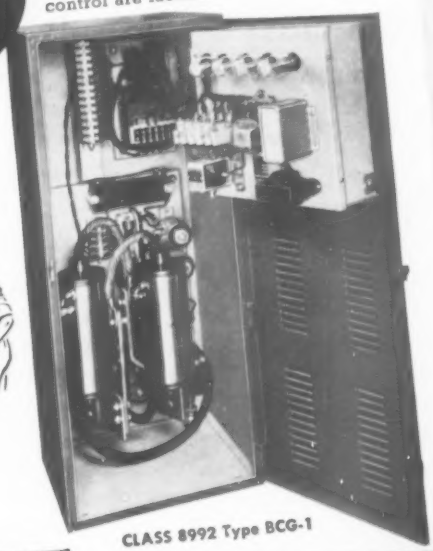


CLASS 8992 Type BBG-1

Electronic

for High Speed Welding

For production line (gun or stationary) welders and other applications where high speed, high currents or dual gun control are factors.



CLASS 8992 Type BCG-1

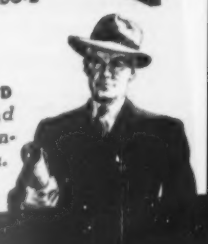
Electronic (SYNCHRONOUS)

for Precision Welding

For welding aluminum, other non-ferrous and ferrous metals requiring precision weld times; stepless heat control; slope or taper control.

CLASS 8993 Type BDG-2

You'll find your nearby **Square D Field Engineer** *a source of sound counsel in selecting the welder control best suited to your application.*



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Welding Arcs

REPORTS FROM WELDORS ON JOBS LIKE THESE INDICATE THAT NEW GENERAL ELECTRIC TYPE W-610-A

Now—Better Welds Faster with G.E.'s

Pipelines, shipyards, fabricators, and builders report many benefits from new AWS Class E-6010 electrode:

PIPELINES Operators like W-610-A electrode because it's easier to use and produces top-flight welds. Slag is easy to remove and "pinholing" is not a problem. The coating does not break down even at high currents. X-rays show excellent deposits and very low porosity.

SHIPYARDS "Now you've got something," say shipyard weldors. On overhead butt welds—one of the toughest shipyard jobs—W-610-A is free of "fingernailing" and "wandering arc." No trouble is caused by reaction pitting. Good set-up prevents undercutting.

FABRICATORS "This is really it! Gas pockets are practically a thing of the past." Weldors prefer the new W-610-A over any other Class E-6010 in the shop. Even on dirty, rusty steel, this new G-E electrode is easy to use. And burn-off rates are high, increasing production.

CONSTRUCTION Weldors welcome the new W-610-A because it's easy to use in all positions and its ability to take high currents speeds construction.

Users have backed up these reports by placing large orders for W-610-A for immediate shipment. But don't take our word on the new W-610-A—find out for yourself. General Electric Co., Schenectady 5, N. Y. 710-4

You can put your confidence in—

GENERAL ELECTRIC

News

Information on equipment, electrodes and accessories from G.E., pioneer in arc welding

ELECTRODE WILL BE INDUSTRY'S NEW QUALITY STANDARD

New W-610-A Electrode

TRY NEW W-610-A YOURSELF at our expense

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General Electric Co.

Why not try this new W-610-A electrode on your toughest mild-steel jobs? Just ask for a free sample from your nearby G-E Welding Distributor. You'll find his name here, and also in the yellow pages of your phone book under "Welding Equipment—General Electric." Contact him today.

Here's the name of your G-E Welding Distributor—

Alabama: Birmingham—Alabama Oxygen, Young & Vann Supply; Mobile—Turner Supply

Arizona: Phoenix—Consolidated Welding Supply

California: Fresno, Los Angeles, Oakland, Sacramento, San Diego, San Francisco, Ventura—Victor Equipment

Colorado: Boulder, Colorado Springs, Denver, Durango, Ft. Collins, Ft. Morgan, Greeley, LaJunta, Longmont, Pueblo—Hendrie & Bolthoff

Florida: Ft. Pierce, Hollywood, Key West, Melbourne, Tampa, Vero Beach, West Palm Beach—Florida Gas & Chemical

Georgia: Atlanta, Macon—Welding Supply & Service; Augusta—Marks Oxygen & Welding Supply; Columbus—Williams Welding Supplies

Idaho: Boise—Olson Manufacturing

Illinois: Chicago, Moline, Morton—Machinery & Welder

Indiana: Evansville—Drill Master Supply; Ft. Wayne, Indianapolis, Richmond—Sutton-Garten; South Bend—Perry Welding Sales & Service

Iowa: Des Moines—Machinery & Welder

Kansas: Coffeyville—Thompson Bros. Supply & Welding Equip.; Hutchinson—Kopper Supply

Kentucky: Louisville—Reliable Welding; Paducah—Henry A. Petter Supply

Louisiana: Alexandria, Shreveport—Hughes Oxygen; New Iberia—Welders Supply; New Orleans—Equitable Equipment; Opelousas—Daigle Welding Supply, Lake Charles—Welders Equip.

Maryland: Baltimore—Arcway Equipment

Massachusetts: Boston—New England G-E Welding Sales Division

Michigan: Detroit—Welding Sales & Engineering; Grand Rapids—Miller Welding Supply

Minnesota: Duluth—W.P.&R.S. Mars; St. Paul—Production Materials

Mississippi: Jackson—Jackson Welding & Supply

Missouri: Kansas City—Hohenschild Welders Supply; St. Louis—Machinery & Welder

Montana: Billings—Valley Welders Supply; Butte, Great Falls—Montana Hardware

Nebraska: Lincoln—Lincoln Welding & Supply; Omaha—Baum Iron

New Jersey: Kenilworth—Welding Sales

New Mexico: Albuquerque—Industrial Supply Co.; Hobbs—Western Oxygen; Las Cruces, Silver City—Car Parts Depot, Inc.

New York: Buffalo—Welding Equipment Sales; Syracuse—Welding Engineering & Equip.

North Carolina: Charlotte—Dixie Gases, Gastonia—Gastonia Motor Parts

North Dakota: Bismarck, Fargo—Acme Welding Supply; Fargo—Dakota Electric Supply

Ohio: Akron, Cincinnati, Cleveland, Columbus, Dayton, Mansfield—Burdett Oxygen; Toledo—Odland Iron Works

Oklahoma: Tulsa—G-E Welding Sales Division

Oregon: Eugene, Portland—J. E. Haseltine

Pennsylvania: Philadelphia, Pittsburgh—Arcway Equipment

South Carolina: Columbia, Greenville—Welding Gas Products

South Dakota: Deadwood—Hendrie & Bolthoff

Tennessee: Chattanooga, Knoxville, Nashville—Welding Gas Products; Memphis—Delta Oxygen

Texas: Abilene—M&M Welding Supply; Alice, Corpus Christi—Crane Welding Supply; Alpine, El Paso, Marfa, Pecos—Car Parts Depot; Amarillo—Tex-Air Gas; Brownsville, Harlingen—Acetylene Oxygen; Dallas—Hill Equipment & Supply; Houston—G-E Welding Sales Division; Lubbock—Welders Supply; Midland—West Texas Welders Supply; Odessa, Pecos—Western Oxygen; Plainview—Plains Welding Supply; San Angelo—Southwestern Welding Supply; Snyder—Western Welding Supply; Texarkana—Hughes Oxygen; Wichita Falls—Nortex Welding Supply

Utah: Salt Lake City—The Galigher Co.

Washington: Seattle, Spokane—J. E. Haseltine

West Virginia: Bluefield—Bluefield Supply; Charleston—Virginian Electric, Huntington, Logan—Logan Hardware & Supply

Wisconsin: Milwaukee—Machinery & Welder

Alaska: Anchorage—Northern Supply

Canada: Toronto—Canadian G.E.

Hawaii: Honolulu—American Factors, Ltd.

company makes products ranging from half-ton electric hoists to huge pulp washers for paper mills. Since the production is, for the most part, a made-to-order business, cost control would appear to be far from simple. However, Mr. McPhee boiled the whole problem down to a simple formula. He then pointed out that management controls 60% of the costs; engineering and design, 35%; and fabrication, just 5%. In other words, if the men in the front office and in the drawing room do a good job, all that the shop has to do is a good day's work every day.

A movie was shown through the courtesy of the Taylor-Wharton Iron and Steel Co. on the making of steel cylinders for compressed gases.

Corrosion-Resistant Castings

Dayton, Ohio.—The *Dayton* Section held its January meeting on the 13th at the Engineers Club. William Dundon, AWS Duriron Co., Dayton, presented a very interesting and informative talk on "Welding of Corrosion-Resistant Castings." Mr. Dundon discussed very thoroughly the repair of foundry defects and fabrication of castings of the stainless varieties. He also covered the changes in metallurgical and physical properties of these materials during the welding process. The proper electrodes to be used as well as the proper preparation for welding was also given.

Mr. Dundon is one of the more active members of the *Dayton* Section and his talk on the subject is one that he actively engages in daily.

Ladies Night

Denver, Colo.—The *Colorado* Section held their second annual ladies night in the Festival Room of the Oxford Hotel on Tuesday evening, Jan. 13, 1953, which started off with an excellent dinner.

Herman Geller, Vice-Chairman, gave an excellent talk on "How Welding Shows Its Effect in the Home" and chose, as the principal, television. He explained in detail how the improvements in television during the last few years were accomplished by welding.

Albert Haanstad, whose hobby and profession is photography, gave a very interesting talk on the flowers of the Rocky Mountain region, illustrated by color film, and also showed pictures of the chipmunks and ground squirrels in their natural habitation.

Juvenile Judge Phillip A. Gilliam gave a very interesting talk on his work with juvenile delinquency and its effect on the people of Denver. Judge Gilliam is an outstanding speaker and his talk was thoroughly enjoyed. The ladies suggested that if each meeting was as interesting as this they would like to attend each month, but if this was not possible, please include them in at least one meeting next year.

Welded Structures

Denver, Colo.—Van Rensselaer P. Saxe AWS, Consulting Engineer, Baltimore, Md., spoke on the subject "Welded Structures" at the January 26th meeting of the *Colorado* Section held at the Oxford Hotel. Mr. Saxe's talk covered the general design of welded structures; symposium and economy of welded structures; safety of welded structures; the practicability and universal use of welded structures; and the speed with which welded structures can be fabricated and constructed. These subjects were of vital interest to all.

Mr. Saxe opened his office of Consulting Engineer in Baltimore in 1920, specializing in structural steel and reinforced concrete work. His first welded structure was designed and built in 1928 and since that time his office has designed and supervised construction of over twelve hundred structures.

Christmas Party

Des Moines, Iowa.—The *Iowa* Section appropriately celebrated the Holiday Season with a Christmas Party held at the Des Moines Golf and Country Club on Tuesday, December 16th. A most enjoyable evening was had by the 46 members and guests present. A delicious dinner in the form of a smorgasbord was served at 7:30 P.M. with refreshments available throughout the evening. Musical entertainment was provided during and immediately following the dinner with nearly everyone joining in a number of old favorite songs. The remainder of the evening was spent playing cards, telling yarns and reminiscing.

The Program Chairman, Robert Rogers, and all those who helped in planning and directing the splendid program, should be congratulated.

Dice Microhm Meter Aids Welding Quality Control

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An essential step in maintaining quality control, improving workmanship and reducing rejects on spot-welding of aluminum is to check surfaces of sheets to determine that they have been properly cleaned. Measuring resistances as low as 1 Michrom, the Dice Model 151-S Microhm Meter quickly shows whether aluminum sheets or other material is properly cleaned. (Low readings shows it is.) Even though the above military specs may not have to be met on your particular product, the Microhm Meter Model 151-S can quickly pay for itself in eliminating rejects and improving quality. Write for free bulletin today.

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Job Shop

Detroit, Mich.—Drawing upon his knowledge and experience, R. R. Beyer AWS, R. C. Mahon Co., presented the many problems of "Fabricating Procedure in a Job Shop" at the January 9th meeting of the *Detroit* Section held at the Engineering Society of Detroit. The factors involved in producing good welds were presented simply and clearly. The illustration of actual jobs were well chosen and very educational as was the film that followed the lecture. The question-and-answer period revealed the large interest of the members in Mr. Beyer's subject.

Coffee speaker was Rex D. Billings, Jr., assisted by Miss R. Ranta of the Eastern Greyhound Lines. Mr. Billings spoke on the "Magic of the Mind."

One hundred and thirty members and guests attended the technical meeting and 67 were present at dinner.

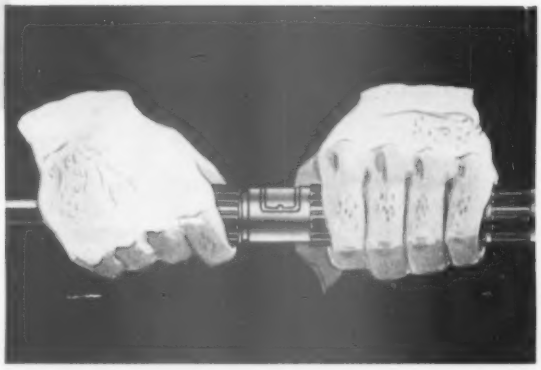
Carbon and Alloy Steels

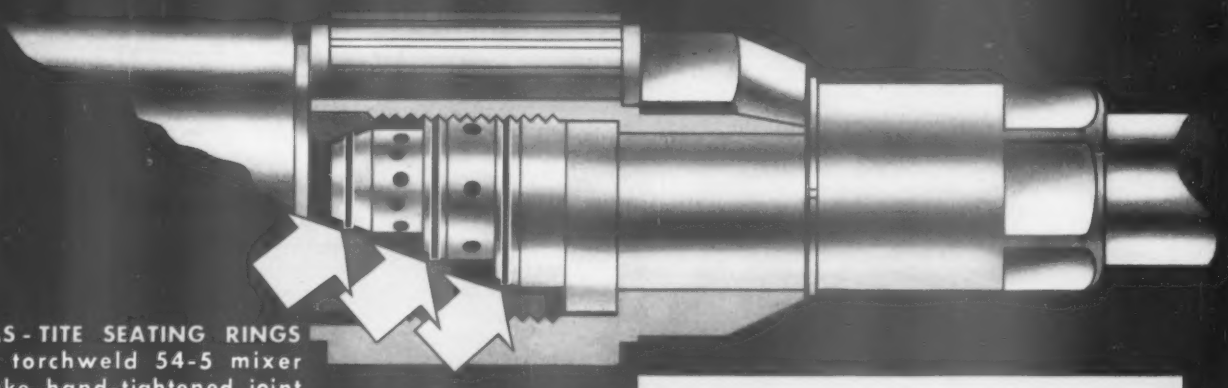
Erie, Pa.—Eric Seabloom, First Vice-President, AWS, and Supervisor of Field Engineering, Crane Co., Chicago, was the speaker at the technical session of the January 20th meeting of the *Northwestern Pa.* Section held at the YMCA. Mr. Seabloom's talk on "Welding of Carbon and Alloy Steels" covered a practical review of a rather technical subject. He covered selection of materials based on physical and chemical properties along with allowable stresses. Mr. Seabloom also dealt with the changes that take place in metals due to welding, how to evaluate them and guard against adverse results. This included carbon steels, low-alloy steels, chromium alloys and stainless steels. Welded joint designs, backing rings, welding techniques, selection of filler metals, preheats and heat treatments were also discussed.

A Section Officers' dinner meeting preceded the technical session with National President Fred Plummer and First Vice-President Eric Seabloom as guests. Information concerning current national policies were discussed and the Section was highly honored by the visit of Messrs. Plummer and Seabloom.

GAS-TITE

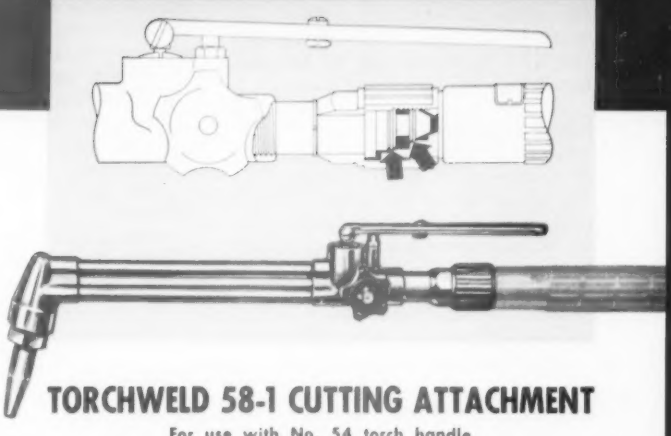
NEW TORCHWELD SEATING RINGS PERMIT GAS-TIGHT JOINTS... with HAND-TIGHTENING





GAS-TITE SEATING RINGS on torchweld 54-5 mixer make hand-tightened joint leakproof. Made of tough, long wearing Servene in flat, gasket design—won't roll off.

- **QUICK COUPLING OF TIPS AND MIXER**—no wrench needed.
- **POSITIVE LEAKPROOF SEATING** even in dusty or sandy atmospheres — without damage to metal seating surfaces.
- **LONGER MIXER LIFE** — Servene seats take all the abuse, are easily and quickly replaced when necessary.
- **LOWER MAINTENANCE COSTS** — eliminates costly periodic re-seating of torch heads.
- **INTERCHANGEABLE DESIGN** — fits any Torchweld No. 54 welding torch handle.
- **LONGER TORCH LIFE** — perfect, gas-tight seal is achieved without strain on threads or seating surfaces.
- **LOWER REPLACEMENT COSTS** — you replace the seating rings, not the entire mixer.



TORCHWELD 58-1 CUTTING ATTACHMENT

For use with No. 54 torch handle

A twist of the wrist and the 58-1 cutting attachment is securely coupled to any Torchweld No. 54 handle. Its newly designed connector plug has Torchweld GAS-TITE seating rings to make a leakproof seal despite condition of seating surfaces. Has features of the heavy-duty No. 75 Torchweld Cutting Torch, including forged bronze head, triangular tube construction and diaphragm type valves.

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Welding of Titanium

Hartford, Conn.—The January 8th dinner meeting of the *Hartford* Section held at Rockledge Country Club, West Hartford, was addressed by Allan J. Rosenberg, General Electric Co., Thomson Laboratory, Lynn, Mass. Mr. Rosenberg gave an excellent extemporaneous talk on "Welding of Titanium" in which he covered new methods of research on the subject.

An excellent sound color film on "Research Orion" was shown through the courtesy of the DuPont Co.

Pressure Piping

Houston, Tex.—The January meeting of the *Houston* Section held on the 28th was highlighted by a very interesting technical session with Eric R. Seabloom of the Crane Co., Chicago, as speaker. Mr. Seabloom is also the first Vice-President of the AWS, Past Chairman of the Chicago Section, member of the Welding Research Council and other engineering societies. His talk was a practical review of a rather technical subject, "Materials, Design, and Welding of Pressure Piping." This subject covered the selection of materials based on their physical properties, creep, graphitization, allowable stresses, and pressure-temperature ratings. The materials covered were carbon steels, low-alloy steels, chromium alloys and the stainless steels. The fabrication of piping covered welded joint design, back-up rings, welded headers and their reinforcement, welding of various alloys, selection of filler metals, preheats and postheats and final heat treatments. Slides accompanied this most interesting talk by Mr. Seabloom.

The technical session was preceded by a steak dinner and a motion picture "Mountain Climbing" with the commentary by Orrin Bonney, a local attorney. This film was a personal film of Mr. Bonney's on mountain climbing in Colorado. Mr. Bonney has been climbing mountains as a hobby for many years and has many climbs to his credit. Mr. Bonney was recently elected Vice-President of the American Alpine Club, a national organization of Mountain Climbers.

Resistance Welding

Indianapolis, Ind.—"Development in Resistance Welding" was the subject of an excellent talk given by Robert Gillette AWS, Precision Welder and Flexopress Corp., at the January 23rd dinner meeting of the *Indiana* Section held at Buckley's Restaurant, Cumberland. Mr. Gillette's extemporaneous remarks covered new methods, applications and processes and was of interest to the engineer, operator and production departments. Slides were used to illustrate the talk.

Stump the Experts

Kansas City, Mo.—The *Kansas City* Section held their monthly dinner meeting Jan. 8, 1953, in Fred Harvey's Pine Room. Thirty-four persons attended the dinner. There were 36 present at the meeting that followed.

The program for this month, entitled "Stump the Experts," consisted of a question-and-answer period. The questions which were submitted by members were answered extemporaneously by a Panel of Experts. Chairman Joe Payne began the program by introducing the panel. They were: Mr. Hollandsworth, The Darby Corp.; Mr. Lindley, The Locomotive Finishing Co.; Mr. Simms AWS, Black, Sivalls & Bryson; Mr. Snyder, Black, Sivalls & Bryson; Mr. Titherington, Ford Aircraft.

L. N. Williams, Technical Representative, acted as judge for this program.

The questions used on this program pretty well covered all fields of welding. It was generally agreed that this type of program was both interesting and informative.

The meeting was adjourned at 9:30 P.M.

Aircraft Production Flash Welding

Los Angeles, Calif.—The January Aircraft and Rocketry Panel of the *Los Angeles* Section was held on the 8th at Swally's Cafe with an attendance of 50 at the dinner and meeting. Charles B. Smith AWS, Chief Process Welding Engineer, Douglas Aircraft Co., Long Beach Division, Calif., presented a paper which was previously given at the Metal Show in Philadelphia on "Aircraft Production Flash Welding." Mr. Smith described in detail the equipment, application and technique necessary to a complete use of flash welding in the aircraft industry.

Some of the points covered were as follows:

1. Advantages of flash welding
   - 1.1 Being done in an automatic machine, the human element is minimized.
   - 1.2 It is many times faster than manual welding.
   - 1.3 Since no filler alloy is used, parent material properties are approached.
2. Steels most widely used in flash welding aircraft components
   - 2.1 SAE 4130.
   - 2.2 SAE 4135.
   - 2.3 SAE 4140.
3. Joint preparation—For the most part a square butt joint is used. The most typical application is joining similar tubes together. Where the two members differ in outside diameter dimensions, the possible difference between the two should not exceed 12.5%.
4. Occasionally it is desirable to harden the steel prior to welding. The annealing effect of flash welding does not soften the jointed parts completely, but enough to reduce the heat-treated strength as shown on the graph (slide No. 3 taken from AWS *Welding Handbook*).
5. Typical parts fabricated by flash welding for the Douglas C-47 and Globemaster are
   - 5.1 Engine control rod, C-47.
   - 5.2 C-47 landing gear; equalizer tubes, side brace members and rear brace strut.
   - 5.3 C-47 engine mounts.
   - 5.4 C-124 landing gear (members).
   - 5.5 Globemaster cargo rings.
   - 5.6 Nose wheel cross beam, consisting of three forgings flash welded together.
6. A flash welding machine can be used for a variety of work other than welding, such as
   - 6.1 Tube buckling operation.
   - 6.2 Upsetting of bar stock for providing extra stock for a stop or bolt head.
   - 6.3 Hot forming—utilizing resistance heating to help form large diameter bar stock into cargo rings.
7. Excellent flash-welded assemblies can be obtained in highly productive quantity with excellent quality providing careful machining is practiced in preparing the parts before welding, and fastidious tooling of the welding machine is maintained.

Inert Gas Welding

Louisville, Ky.—Edward H. Roper AWS, Manager Technical Sales, Air Reduction Sales Co., New York, rewarded those present at the January 27th meeting of the *Louisville* Section with an excellent talk on "Inert-Gas-Shielded Arc Welding." An equally excellent film of slides illustrated the application of the consumable electrode used in conjunction with the inert-gas shield. Mr. Roper indicated that the various types of welding have their own application and that this latest development in welding was primarily for high-speed reduction with high-quality welds.

After receiving his B.Sc. in Mechanical Engineering from Yale University in 1932, Mr. Roper gained considerable field experience in mines and oil fields and then in 1936 joined the Air Reduction Sales Co. Since then he has been associated primarily with their technical sales division. Mr. Roper is a licensed professional engineer in New York State, a member of a number of technical societies, and author of several books and technical papers on oxygen cutting and gas-shielded arc welding.

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FLOWLINE Welding Fittings are handled throughout the country by leading distributors who sell everything for corrosion-resistant piping —fittings, valves, pipe, and accessories. This phase of our specialization in corrosion-resistant fittings helps users obtain "on-the-job" service — and take fullest advantage of the economy and efficiency of simplified welded construction.
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FLOWLINE corrosion-resistant fittings include tees, stub ends, ells, reducers, and caps. All are made of close-grained forged or wrought metals, cold formed by our exclusive process and annealed, which consistently puts the metal in the best condition for corrosion service. These fittings are normally stocked at strategic points in Schedules 10, 40, and 80 (Schedule 5 also available)—sizes ½" through 12" — in stainless steel Types 304, 316, 347; Monel; Nickel.
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year enjoyed the valuable session. The dinner and meeting were held at Kapfhammer's Party House.

Meetings and Events

Milwaukee, Wis.—The regular monthly meetings of the *Milwaukee* Section will be held on March 27th and April 24th. The annual party will be held on May 16th.

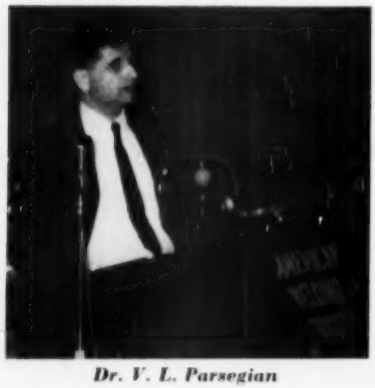
Jigs and Features

Newark N. J.—The December 16th meeting of the *New Jersey* Section was held at the Essex House with 75 members and guests in attendance. The principal speaker was Cecil C. Peck AWS, President of the Cecil C. Peck Co., who gave a very interesting talk on the advantages and benefits that can be derived from proper jigs and fixtures for production welding. Mr. Peck's talk was completely illustrated with numerous slides and interspersed with occasional humor that was well received.

The after meeting refreshments were also enjoyed by all.

Atomic Power Plant

Newark, N. J.—On January 20th a joint meeting of the *New Jersey* Section was held with the American Society for Mechanical Engineers in the Terrace Room of the Essex House Hotel. The guest speaker of the evening was Dr. V. L. Parsegian, Director, Research Division, U. S. Atomic Energy Commission. The subject of Dr. Parsegian's enlightening talk was "Some Problems of the Atom Power Plant." As an introduction, a film entitled "Unlocking the Atom" provided a good background for the presentation. Dr. Parsegian used slides and a model to illustrate various reactor arrangements and methods of operation for the production of atomic power. One of the most interesting phases of the subject was the problem of finding suitable materials of construction for fabricating these atomic plants because most of the materials under consideration are not generally used.



Dr. V. L. Parsegian

Dr. Parsegian received his B.S. degree in Physics from the Massachusetts Institute of Technology in 1933 and his Doctorate in Nuclear physics from NYU in 1948. He is a member of the honorary Physics Society, Sigma Pi Sigma, and has published articles on nuclear research, nuclear instrumentation, industrial instrumentation and pyrometry.

There were 102 members and guests present. The usual after-meeting snack and refreshments provided an opportunity to visit friends and members of the ASME.

Meetings for the remainder of the season are as follows:

March 17—Subject: "The Selection of Welding Processes for Specific Fields of Application." Speaker: A. U. Welch, AWS, Manager of Engineering, General Electric Co., Welding Dept.

April 21—Subject: "Product Design for Welding." Speaker: T. B. Jefferson AWS, Editor, *The Welding Engineer*.

May 19—Subject: "Welding of the Super Alloys for Extreme Temperatures." Speaker: G. Parks AWS, Solar Aircraft Co.

Plant Tour

Peoria, Ill.—On Wednesday, December 17th members of the *Peoria* Section were guests of the Keystone Steel and Wire Co., Bartonville, Ill., in a plant tour of their wire mill.

Design of Welded Ships

Philadelphia, Pa.—Harold Acker, Bethlehem Steel Co., gave a technical talk on "Application of Research to Design of Welded Ships" at the December 15th dinner meeting of the *Philadelphia* Section held at the Engineers Club. Mr. Acker used slides to illustrate his talk which was of general interest to the engineer.

One hundred and ten members and guests were present at the technical session and 55 at the dinner.

Jet Engines

Philadelphia, Pa.—The regular monthly dinner meeting of the *Philadelphia* Section was held on January 19th at the Engineers Club with an attendance of 56 at dinner and 125 at the technical meeting.

P. Gordon Parks AWS, Welding Engineer, Solar Aircraft Co., spoke extemporaneously on the "Welding of Jet Engines." Slides were used to illustrate this semitechnical talk.

Welding Aluminum

Phoenix, Ariz.—The *Arizona* Section met in the Aluminum Room of the Hotel Westward Ho on January 21st for its regular monthly meeting. Following dinner, Charles Bruno AWS, Chief Welding Engineer of the Reynolds Metals Co., gave a very fine talk on "Welding Aluminum."

Mr. Bruno, who has appeared before many other groups, has a background of wide experience in the welding field. When he joined Reynolds in 1945, he was in charge of all welding operations, welded designs and welding equipment, as well as the company's welding school. In 1947 he was placed in the Technical Service Department and later in the Products and Applications Department where his services as Chief Welding Engineer are being made available to help Reynolds' many customers with their welding problems.

Mr. Bruno gave a very lucid presentation of the effect of the oxide on the aluminum base metal in the welding operation and means used to break down this oxide film to secure sound weld. Jig design and weld design were brought to the listener's attention also. Everyone agreed that Mr. Bruno's talk was one of the finest ever given before the Section and all the members are grateful for his coming to Phoenix to speak.

Metals Joining Symposium

Pittsburgh, Pa.—A get-together dinner at Webster Hall preceded the monthly meeting of the *Pittsburgh* Section held on January 21st. The meeting held in the auditorium of the Mellon Institute of Industrial Research was in the nature of a metals joining symposium with the following panel members and their subjects:

W. D'Orville Doty AWS, Welding Metallurgist, United States Steel Corp., "Carbon Steels."

J. R. Hunter AWS, Welding Metallurgist, Atomic Power Division, Westinghouse Electric Corp., "Nonferrous Alloys."

H. F. Reid AWS, Head of Technical Service, Welding Electrodes Division, McKay Co., York, Pa., "Stainless Steels."

The moderator was Joseph W. Kehoe, AWS Secretary Manager, Headquarters Manufacturing Engineering Metals Joining Laboratory, Westinghouse Electric Corp., East Pittsburgh.

The speakers discussed some of the metallurgical problems and recommended procedures in the welding of materials assigned to them in the above subjects.

The AWS film "Applied Welding Engineering" was shown at the beginning of the meeting.

There was an attendance of 114 at this meeting.

Pressure Pipe Welding

Rochester, N. Y.—Eric R. Seabloom, First Vice-President AWS and Supervisor of Engineering, Engineering Division, Crane Company, Chicago, was the guest speaker at the January meeting of the *Rochester*, N. Y., Section held at the Rochester Turners Club.

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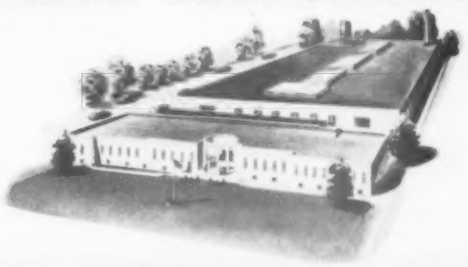

PRIZE COMPETITION FOR CONTRIBUTIONS TO THE SCIENCE AND ART OF "NON-FUSION" WELDING, BRAZING AND SOLDERING

Rules:

OPEN TO:
Engineers, Metallurgists, Research Investigators, Welders, Students, Faculty Members and all others qualified.

Covering technological and research aspects, procedures and applications of the use of lower melting (lower than parent) filler metals in the non-fusion welding processes.

The Jury and Committee of Awards:

1. Dr. Robert Humphrey, former Vice Chairman, American Society for Metals
2. Prof. Otto H. Henry, Dept. of Metallurgy, Polytechnic Institute of Brooklyn
3. Dr. Th. I. Leston, Vice President, Eutectic Welding Alloys Corporation

ELIGIBILITY

1. The Prize Contest is open to single individuals or groups of two or more, except employees of the Eutectic Welding Alloys Corporation, its subsidiaries and affiliates, its Advertising Agencies and its Distributors.

2. Each paper submitted must be original and previously unpublished. Moreover, each contestant must have actively participated in the work and preparation of the subject matter of the manuscript.

3. Participation necessitates submission of a paper of not less than 1,000 words, exclusive of drawings, specifications, tables, photographs, etc.

SUBJECT MATTER

1. The subject matter shall pertain to one of the following:

Classification A—*Basic principles, theory and results of research* in the field of "non-fusion" welding, brazing or soldering. (The metallurgical considerations of these processes may include Surface Alloying, diffusion, wetting, spreading, fluxing, equilibrium and non-equilibrium reactions, solidification, etc.).

Classification B—*Practical welding applications*—(The manuscript may be based upon the design or redesign of equipment, structures, and other products of ferrous or non-ferrous materials fabricated by "non-fusion" welding, brazing or soldering. Technical advantages of these processes and savings in material and labor should be considered and substantiated. Improvements in brazing and soldering techniques might also be the subject of the manuscript.)

2. Photographs, drawings, charts or test data which will add clarity to the presentation should be included.

SUBMISSION

1. Manuscripts should be typed in English, double spaced on 8½" x 11" white paper, with any drawing and photographs on separate sheets, preferably attached to the text. The manuscript should be securely bound and have a protecting cover.

2. Papers must be submitted in duplicate. One copy must be signed by the author (or authors) and enclosed in a separate sealed envelope, with the following information on the cover sheet (1st page) of the manuscript and on the outside of the envelope:

Name
Address
Signature
Company (or University) affiliation
Classification ("A" or "B") under which paper is submitted.

A duplicate of the paper, unsigned and unidentified as to author and application, should be enclosed in a second envelope.

The two envelopes should be placed in a large envelope and mailed to The Secretary, Prize Competition, Eutectic Welding Alloys Corporation, 172nd Street and Northern Boulevard, Flushing 58, New York, N. Y.

This procedure insures that all manuscripts are treated confidentially by the Jury. After the unidentified papers have been judged, the identification with the original paper on file with the secretary will be made and the prizes will be paid to the winners.

JUDGING

The papers will be judged by the Jury and Committee of Awards. In classification "A" the primary considerations are (1) originality, (2) understanding of basic principles, (3) merit of research results, (4) clarity of illustrations and data presented. In classification "B" the primary considerations are (1) originality, (2) material and labor savings, (3) improvement in efficiency and service life and (4) design and welding procedures.

Decision of the judges will be final. All entries and ideas become the property of The Eutectic Welding Alloys Corporation, and none will be returned.

CONTEST DEADLINE

All manuscripts have to be submitted and postmarked no later than August 31, 1953. Winners of awards will be notified approximately within (60) days after the close of the competition.

All communications and questions should be addressed to The Secretary, Prize Competition, Eutectic Welding Alloys Corporation, 172nd Street and Northern Boulevard, Flushing 58, New York.

Helpful suggestions on the preparation of the paper and on possible topics are available and will be sent upon request.

AWARDS

CLASSIFICATION A: Basic Principles, Theory and Results of Research		CLASSIFICATION B: Practical Welding Applications	
First Prize	$500	First Prize	$200
Second Prize	300	2 Second Prizes..each	100
Third Prize	200	3 Third Prizes..each	50
3 Fourth Prizes..each	100		
3 Fifth Prizes..each	50		

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WJ-3

Mr. Seabloom gave a practical review of carbon and alloy-steel pressure piping, accompanied by many slides. He particularly stressed the importance of pipe joint design—both good and bad, with the end results of same. Mr. Seabloom also pointed out the importance of using qualified welding procedures with the use of proper preheat and postheat treatments to obtain optimum results.

Much interest was created by a procedure eliminating the use of back-up rings in pipe joints. This process is used to some extent by the Crane Co. The mating ends of the pipe are beveled to a predetermined bevel leaving approximately $^1/_{16}$ in. interface land. The pipe ends are butted tight together. Best results are obtained by first purging the inside of the pipe with an inert gas (such as argon) then using it as a shielding medium while a wash pass is applied from the outside with the tungsten inert gas process without the addition of filler metal. A very lively question-and-answer period followed.

Low-Hydrogen Electrodes

Saginaw, Mich.—A. Clemens, Jr., AWS Director of Research and Welding Engineering, Arcrods Corp., Sparrows Point, Md., spoke before the January 8th dinner meeting of the *Saginaw Valley* Section held in the High Life Inn, Saginaw. Mr. Clemens' topic was "Low-Hydrogen Electrodes." His subject was presented against a background of the performance characteristics of conventional electrodes. The talk was semitechnical in nature and appealed to the welding engineer, shop manager and welding operator. Low alloys were also touched upon.

Mr. Clemens has been with the Arcrods Corp. since June 1940 having come to Arcrods from the Physics Department of the Graduate School of Johns Hopkins University.

Family style ham and beef dinner was enjoyed by 42 members. An attendance of 45 was present at the meeting. The attendance was lower than usual due to a severe sleet and snow storm.

Brazing

Schenectady, N. Y.—The 4th meeting of the *Northern New York* Section was held at Reich's Restaurant, Route 9, Albany-Saratoga Road on Thursday, Feb. 5, 1953.

The main speaker was Arthur N. Kugler AWS, Technical Sales Department of the Air Reduction Sales Co., who spoke on the subject "Brazing and Braze Weld Application."

Mr. Kugler is well qualified to speak on both the technical and the practical applications of brazing. He has specialized in the application of welding and brazing to various industries. He has done extensive work on the welding of piping for oil, gas, steam and water service. He has participated in the development of multilayer Oxy-acetylene welding and the welding of carbon-molybdenum steel pipe. He is the author of many papers on welding and welding design.

He has been associated with many technical committees of the AMERICAN WELDING SOCIETY, the American Standards Assn., Society of Tool Engineers, the American Society of Mechanical Engineers and others. He is a professional engineer and has served as instructor in welding engineering at Pratt Institute and as consultant on welding engineering to the Edgewood Arsenal. He has prepared many welding sections of handbooks and textbooks; for example, *Marks Mechanical Engineers Handbook* and the *American Machinists Handbook*.

Ladies' Night

South Bend, Ind.—The *Michiana* Section enjoyed their fourth Ladies' Night on January 15th with a dinner in the Mayfair Restaurant in Mishawaka, followed by a talk on "Man Made Fibers" by J. B. Shelnutt of Product Information Division of E. I. du Pont de Nemours & Co. Mr. Shelnutt's nontechnical discussion of rayon, nylon, orlon and dacron fibers and fabrics was well received. Samples of different fabrics were available for inspection.

Mr. Shelmutt pointed out various phases of the textile problems. For instance, these fibers themselves are less expensive than wool, but garments made from them sell for higher prices because of manufacturers having to learn how to sew them, new machinery being required in many cases, and because the demand exceeds the supply.

Nylon is the strongest of the fibers, dacron and orlon following in that order. The need for several fibers is explained by the fact that other properties, such as drape, resiliency, etc., also enter into the garment picture as well as strength. Static electricity can be temporarily reduced (until the next washing) by making the final rinse in a detergent solution and letting the fabric dry with that compound in place.

A host of details such as these provided a very instructive evening for the welders and their wives.

NonFerrous Alloys

Springfield, Mass.—John W. Mortimer AWS, Whitlock Metals, Inc., Hartford, Conn., was the guest speaker at the dinner meeting of the *Western Massachusetts* Section held on January 13th at Blakes Restaurant. Mr. Mortimer's clear-cut remarks on the subject "Welding of Nonferrous Alloys" were highly interesting. An untitled new film of the Whitlock plant and operations was shown in conjunction with the paper and was very well received.

Resistance Welding

Toledo, Ohio.—F. R. Woodward AWS, Taylor Winfield Corp., presented a highly interesting discussion on "Resistance Welding as a High Production Tool" at the January 8th dinner meeting of the *Toledo* Section held in Link's Cafeteria. Slides were used to illustrate Mr. Woodward's discussion.

Sigma Welding

Wichita, Kan.—The January 12th meeting of the *Wichita* Section began with a tour of the new Vocational Ag Building at East High School. This was a highly educational tour and gave the members a chance to see the amazing advantages that the youngsters of today take for granted. Dinner was served following the tour, after which the technical meeting was opened.

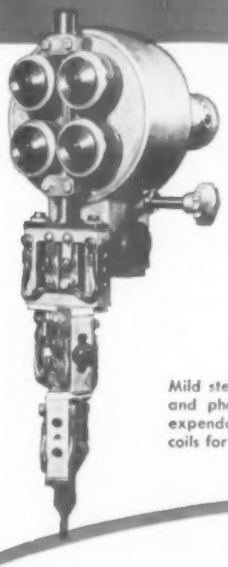
Speaker for the evening was J. E. Dato, Vice-President, AWS, District No. 6 and Assistant Manager Process Service, Southwestern Region, Linde Air Products Co. Mr. Dato spoke on "Shielded-Inert-Gas Metal Arc Welding," known as sigma welding. A 16-mm. color picture on the subject and also a 16-mm color and sound picture on "Mechanized Cutting Machines" was shown in connection with the talk.

Panel of Experts

York, Pa.—One of the outstanding meetings with an attendance of 65 was held on Monday, January 5th, by the *York-Central Pa.* Section in the Pine Tree Inn. Leonard W. Williams AWS, manager of the technical service department, Lukens Steel Co., Coatesville, was the principal speaker. Mr. Williams participated with a panel of experts in a question-and-answer

Leonard W. Williams

Every Welding Need

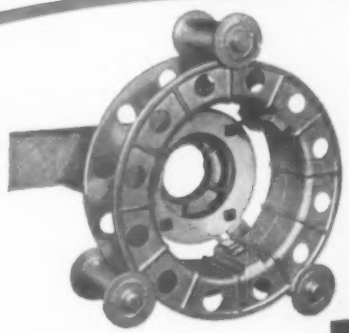


The Reid-Avery type 4R automatic head and control originally designed for Raco composite type A, may be used with equal success for lightly coated open arc or for submerged arc welding.

Raco composite type A heavy coated automatic (open arc) electrodes, a "Reid-Avery" first, can be furnished in all mild steel, low alloy high tensile, low hydrogen, hard surfacing and stainless steel grades.

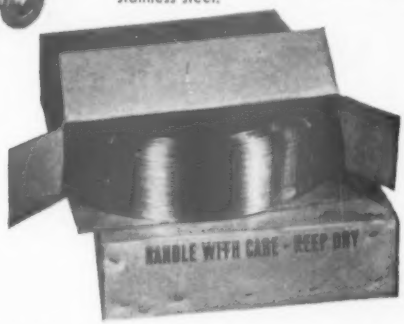
Mild steel, alloy steel, stainless steel, aluminum and phosphor bronze wire are available on expendable wooden spools or in layer wound coils for gas shielded arc welding.

The Raco "free unreeling" reels are especially designed for high speed automatic machines. The ball bearing trunnions enclose the coil so there is no over-run or loose strands and larger coils can be used. Changing coils is a matter of only a few seconds and no tools are required. Available in 12, 14, 25 and 36 inch sizes, for any weight from 50 to 200 lbs.



The Raco coils of wire for submerged arc welding have long been known for their uniform high quality and convenient, easy to handle package. Special attention is paid to the accurate weight, lay and temper of the wire so that the wire will accurately follow a seam. Available in mild steel, alloy steel and stainless steel.

Since 1919 Reid-Avery Company has specialized in the manufacture of all types of welding electrodes and wire. The large modern plant in Baltimore is equipped for wire drawing, annealing, pickling, coating, cutting, winding and packaging. Every phase of welding electrode and wire production is completely controlled from start to finish. You can be assured of uniform high quality and the best possible deliveries.



We also manufacture a complete line of manual electrodes in the following grades:
Raco Mild Steel, Raco Low Alloy High Tensile, Racocast for nonmachinable welds on cast iron, Raco Feral for welding aluminized sheets, Raco Low Hydrogen, Raco Hard Surfacing, Racolloy Stainless, Racolloy Nickel and Nickel 60 for machinable welds on cast iron.

The REID-AVERY COMPANY

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SINCE 1919 PRODUCERS OF ARC WELDING ELECTRODES AND WELDING RODS

period which followed the showing of an hour-long color film on the subject of arc welding.

The other panel members were Jack Cavanagh AWS, technical director, Alloy Rods Co.; William Lutes AWS, McKay Co. and David Walters AWS, arc and gas welding instructor, William Penn Senior High School.

Mr. Williams became associated with the Lukens Steel Co. as a salesman in 1945. The following year he became a welding service engineer in the technical plates sales department and subsequently senior welding engineer in the technical service department. Mr. Williams studied chemical engineering at both Pennsylvania State College and the Drexel Institute of Technology.

Employment Service Bulletin

Services Available

A-634. Naval Shipyard Welding Engineer. B.S. in M.E., age 48, married. Twenty-four years service as Welding Engineer in U. S. Naval Shipyard, 15 years in laboratory development work and for the past nine years Chief Welding Engineer on construction and maintenance of all types of naval vessels. Organized and operating production radiological teams for field inspection of weld assemblies. Familiar with all codes. Presently employed but due to arbitrary Civil Service regulations have no prospects of pecuniary advancement. Minimum salary acceptable $11,000 per year. Excellent references available from recognized sources.

Positions Vacant

V-286. Welding Engineer GS-12 Grade, starting salary $7040. Minimum of ten years' experience in the field of shipbuilding is preferred but not required. Position is responsible for application of welding and allied processes in the construction and repair of Naval Vessel hulls and components. See instructions below.

V-287. Welding Engineer GS-11 Grade, starting salary $5940. Minimum of five years' experience in high-temperature, high-pressure pipe, and pressure vessel welding and turbine fabrication as applied to Naval construction. See instructions below.

V-288. Welding Engineer GS-9 Grade, starting salary $5060. Minimum of three years' experience in machinery fabrication. See instructions below.

Positions are located in the Welding, Casting and Forging Branch of the Bureau of Ships, The Department of the Navy, Washington 25, D. C. Qualified candidates should complete C.S.C. Form 57, which may be obtained from any U. S. Post Office or Civil Service Commission Office and forward to Code 592 at the above address.

the D-C Rectifier Welder with ARC-DRIVE CONTROL

...Instantaneous response to arc-load changes
...Instantaneous recovery
...Reduced arc blow
...Completely adjustable by operator

Westinghouse RA Welders with new positive arc-drive control now prevent shorting when used on "drag" welding applications. In addition, they allow complete penetration on root passes of vertical and overhead welds. Arc-drive control is obtained by adjusting the ratio of short-circuit current to welding current without changing open-circuit voltage. Actual amount of arc-drive current can be varied by the operator.

For information on this improved RA Welder or other Westinghouse Welding Equipment, write Westinghouse Electric Corporation, Dept. DC70, Welding Division, Buffalo, New York. J-21607-A-1

YOU CAN BE SURE...IF IT'S Westinghouse WELDING EQUIPMENT

ENGINEERS, WELDING

Excellent opportunity for engineers with a metallurgy degree or equivalent, having alloy welding experience and supervisory potential.

1. Research and development on manual and automatic welding procedures for low-alloy and stainless steels and heat-resistant alloys.

2. Production welding control and vendor contact. Involves investigation and correction of shop welding problems. All types of welding methods and materials encountered. Knowledge of resistance welding desirable, not essential.

Please send details of experience, education, age and expected salary to

K. Warrick, Wright Aeronautical Division
Curtiss-Wright Corporation, Wood Ridge, N. J.

WELDING RESEARCH MANAGER

Metallurgical and or welding engineer with supervisory abilities to organize and develop a new operation in welding research. Should have a thorough scientific understanding of the fundamentals of welding metallurgy in addition to some operating experience. Replies will be kept confidential. Box V-289.

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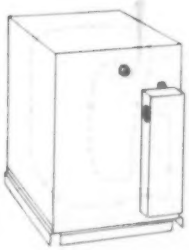
Aridair

ELECTRODE
Moisture Content
STABILIZER

worth its weight in gold

FOR
Low Hydrogen
and
Stainless Steel Electrode
Arc Welding Applications

Specifically designed and engineered to maintain correct moisture content.



EXCLUSIVELY ARIDAIR

- *Chemically dried air*
- *Shelf circulation*
- *Electrically heated*
- *Thermostatically controlled*
- *Recessed shelving*
- *Rigid construction*
- *Multiple unit stacking*

Fred C. Archer, Inc.

MANUFACTURER
MILWAUKEE 3, WISCONSIN

abstracts of
CURRENT WELDING PATENTS

prepared by V. L. Oldham

Printed copies of patents may be obtained for 25c from the Commissioner of Patents, Washington, D. C.

2,623,576—Cutting Torch with Inclined and Offset, Cutting Oxygen Discharge Passage—Petrus W. M. M. de Jong, Hendrik G. van Huls, and Jacob Ridderikhoff, Delft, Netherlands, assignors to Shell Development Co., San Francisco, Calif., a corporation of Delaware.

This patent relates to a cutting torch for making oblique cuts in metallic bodies by means of a preheating flame burning a heating gas and a cutting oxygen jet. The cutting torch includes a burner nozzle having a discharge orifice for directing combustible gaseous mixtures against surfaces to be cut. A heating gas and oxygen are supplied to the burner nozzle, while a cutting nozzle is provided for directing an isolated jet containing only cutting oxygen against the surface of the body to be cut. Such cutting nozzle is inclined at an angle of about 30° to the axis of the cutting torch and it is offset from the longitudinal axis of the torch.

2,623,577—Gas Welding and Cutting Tip—Irving Cowles, Chicago, Ill.

Cowles' patent relates to a nozzle piece for fluids and it includes a shell member with a core member mounted within the shell member and bounding a flow chamber therebetween. A plurality of inlet means for a plurality of fluids is provided at the inlet end of the shell member while helical means are provided in a portion of the flow chamber for changing the direction of flow of a greater proportion of the mixture of fluids to provide for better mixing within the flow chamber.

2,623,972—Spot Welding Machine—Bernard Gross, San Diego, Calif., assignor to Rohr Aircraft Corp., Chula Vista, Calif., a corporation of California.

The patented Spot Welding Machine comprises a pair of electrode holders with a pair of welding electrodes connected to such electrode holders. A manual control member is provided for controlling the position of the electrode holders and such control member is adapted to move both electrode holders as a unit to change the distance of the electrodes from the remainder of the machine, or to actuate only one of the electrode holders and thereby change the distance between the welding electrodes.

2,623,973—Pipe Flash Welder—Sven Malke, Milwaukee, Wis., assignor to A. O. Smith Corp., Milwaukee, Wis., a corporation of New York.

This patented welding machine relates to the flash welding of opposed longitudinal edges of a tubular blank, and it includes a pair of rockers carried by a frame and arranged opposite each other for inward operation upon a tubular blank, and a pair of dies are movably mounted on the rockers for engagement with the back of the blank to aid in shaping it to tubular form. Means are provided by the rockers for moving the pair of dies to clamp the blank against a pair of forming dies and means supply welding current to the full length of the blank edges. Other means actuate the rockers and thus the dies to move the blank edges together and apart and effect flash welding thereof.

2,623,974—Process for Extruding Flanges Around Holes in Metal Sheets and Welding Nuts Thereto—Frank M. Prucha, Birmingham, Mich., assignor to General Motors Corp., Detroit, Mich., a corporation of Delaware.

This patented process comprises extruding the sheet at the edge of a hole formed in the sheet to form a flange around such hole, and a nut is held against the flange so that the corners of the nut rest thereon. Pressure is applied to the nut and a welding current is also supplied to the nut and the sheet to cause the corners of the nut to become embedded in the flange provided on the sheet.

2,623,975—Method of Welding Molybdenum—Ward W. Watrous, Jr., Chatham N. J., assignor to Chatham Electronics Corp., Newark, N. J., a corporation of New Jersey.

This welding method relates to the welding of two pieces of molybdenum and includes the steps of depositing a layer of flux material on the surfaces to be joined wherein the flux comprises a mixture of equal parts of powdered molybdenum and powdered nickel. The pieces are heated in a furnace to a temperature in the range of 950 to 1150° centigrade for at least ten minutes and the pieces are next spot welded together by the application of pressure and transmission of electric current therethrough.

2,624,483—Carrier for Welding Outfits—Edward E. Ketzel, Dayton, Ohio.

This patent relates to a retaining unit for a welding outfit adapted for holding the outfit in position during operation and for transporting it as a highway vehicle. The unit includes a frame and means thereon for holding a plurality of gas containing cylinders for welding spaced from the frame. The frame can either be manually pulled about, or it may be pulled about by vehicle, and the frame may be tipped in one direction to aid in the loading and unloading of cylinders onto and from the frame.

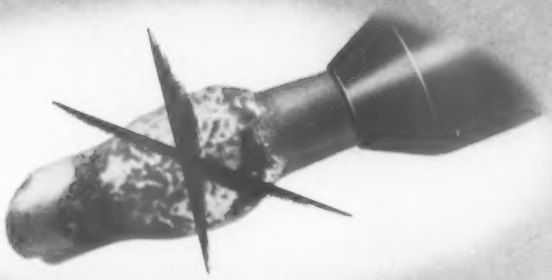
2,625,637—High-Frequency Induction Welding Apparatus and Process—Lloyd P. Garner and William N. Parker, Lancaster, Pa., assignors to Radio Corporation of America, a corporation of Delaware.

This patent relates to an induction welding system including an oscillator. The patent particularly relates to an improvement wherein a modulator and a timer are used for controlling the output of the oscillator so that the welding cycle can be provided including a relatively long preheat period, a relatively short welding period, and a relatively long postheating period for securing a good weld. The modulator and timer include a plurality of stators of arcuate form and which are circularly arrayed.

2,625,638—Welding System—Harold J. Graham, Highland Park, Mich., assignor to Graham Manufacturing Corp., Ferndale, Mich., a corporation of Michigan.

This patent relates to electric welding apparatus comprising a relatively movable primary and secondary winding, motor means for driving the windings, and fly wheel means are coupled to the motor means and responsive windings. A source of exciting current, including a capacitor means, is connected to the primary winding and relatively movable electrode means are connected to the secondary winding. A special excitation circuit is provided and has in series connection the primary winding, capacitor means, and electrodes connected in the secondary winding.

2,625,639—Seam Welder Head—Edwin A. Mallett and Melvin M. Seeloff, War-

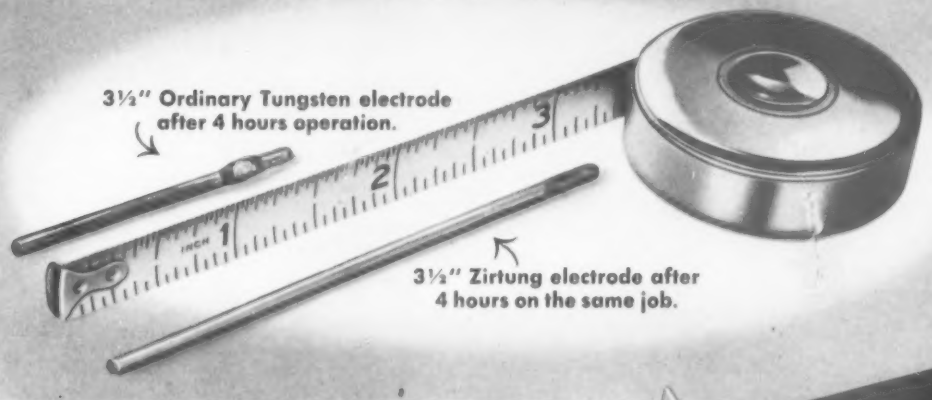


CROSS OUT CONTAMINATION AND SAVE WITH ZIRTUNG ELECTRODES

Work right ahead without interruption with Sylvania's new Zirtung electrodes!

This improved tungsten-zirconium rod really licks the contamination problem and lasts longer on any job. Saves time, saves electrodes and assures sound, dependable welds. Wonderful for mild steel, stainless steel, aluminum, and magnesium. If your nearest Sylvania Welding Distributor can't supply you, write today to: Sylvania Electric Products Inc., Dept. 3T-4903, 1740 Broadway, New York 19, New York.

An exclusive Sylvania development!



Here's why Zirtung saves:

1. **Greatly reduces electrode consumption.**
2. **Less contamination from material being welded.**
3. **Self cleans contamination without loss of electrode.**
4. **Greater arc stability.**

SYLVANIA

TUNGSTEN & CHEMICAL PRODUCTS; RADIO TUBES; TELEVISION PICTURE TUBES; ELECTRONIC PRODUCTS; ELECTRONIC TEST EQUIPMENT; FLUORESCENT LAMPS, FIXTURES, LIGHT BULBS; PHOTOLAMPS; TELEVISION SETS

ren, Ohio, assignors to the Taylor-Winfield Corp. Warren, Ohio, a corporation of Ohio.

Apparatus for rotatably supporting and conducting welding current to a rotary resistance welding electrode is shown in this patent. A projecting support is provided that has a longitudinal bore adjacent its free end, a shaft anti-frictionally journaled in said bore and a tapered outer end portion, while a hub of current-conductive material is mounted on the tapered outer end portion and is adapted to mount the rotary welding electrode. The apparatus also includes a current conductive member having a pocket fitting over and about the free end of the support and having an integral collar portion encircling the outer taper of the hub at one end of the bore. The patent relates to the particular positioning of the collar on the hub and the forces exerted on such members.

2,625,651—Welding Control—Joseph F. Schmidt, Scotch Plains, N. J., assignor to General Motors Corp., Detroit, Mich., a corporation of Delaware.

Schmidt's patent relates to control means wherein a work system is controlled that has a plurality of sequentially actuated portions which additively compose a complete cycle of operation for the system. Control means are provided for each portion of the system and the control means are interlocked to inaugurate the next succeeding portion at the conclusion of its own period. A group of adjustable time control circuits are connectable to the control means to determine the energization time and duration for each portion, while a second group of adjustable time control circuits are connectable to the control means. A compound switching means is connected to the two groups of time control circuits and to the control means to alternatively connect one complete group or the other to the control means to provide operation cycles consisting of different portion intervals.

2,626,367—Welding Generator—Marshall Beymer, Chicago, Ill., assignor of one-half to Henry L. Sweitz, Chicago, Ill.

An alternating current machine for furnishing high-amperage, low-voltage current is disclosed in the patent and includes a stator having a plurality of coils arranged in parallel, and a rotatable shaft extending through the machine and positioning a rotor for inducing current in the coils. The rotor has the same number of magnetic members as there are coils and is adapted to rotate in phase with the coils and being of alternating polarity. A current control device is present in the apparatus for rendering any selected number of the coils effective and the control device includes a plurality of arcuately arranged stationary contacts. A contact sector is rotatably mounted on the shaft and is adapted to engage with any selected number of the contacts for determining the number of coils rendered effective at any time.

2,626,339—Welding Rod—Rene D. Wasserman, Stamford, Conn.

This patented welding rod is designed particularly for the welding of copper and high copper alloys. The rod contains between 50 and 100% nickel and the remainder, if any, is copper. The rod has a coating which consists of 20 to 60% of a heavy metal fluoride, 15 to 45% of a heavy metal carbonate, 5 to 15% carbonaceous material, and a binder comprising a 12 to 22% solution of silicate of at least one of the metals of the groups consisting of sodium and potassium.

LIST OF NEW MEMBERS

Effective January 1, 1953

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Bennett, Marvin J. (B)
Boggs, Garold E. (C)
Foster, Donald R. (B)
Mikesell, Calvin W. (B)
Minton, Robert S. (B)
Stevenson, Arthur M. (C)

BIRMINGHAM

Black, J. T. (C)
Bowen, W. B. (B)
Branum, Donald R. (C)
Conner, Robert E. (C)
Cooper, Belton Y. (B)
Greenup, Marion A. (C)
Hall, Wilmer E. (B)
Hughes, Thomas H. (B)
Little, John W. (B)
McCain, W. W. (B)
McGee, Nick C. (C)
Norwood, Holden B. (C)
Obermark, A. F. (C)
Rogers, Edward M., Jr. (B)
Skipworth, J. E. (C)
Temple, Ben H. (C)
Thomas, O. G. (B)

CHATTANOOGA

Thurman, H. R. (C)

CHICAGO

Smith, Sheridan S. (B)

CINCINNATI

Hall, James J. (B)
Sullivan, Howard J. (C)

CLEVELAND

Abel, Paul J. (A)
Bodin, Arthur W. (B)
Bodwell, John W. (B)
Hegerty, William J. (B)
Liszkay, Charles (C)
McAsor, George W. (C)
Rowlands, Edward W., Jr. (B)
Swider, John C. (C)
Williams, Robert N. (C)

COLORADO

Anderson, A. K. (B)
Hagarty, T. J. (B)
Morgenegg, E. E. (B)
Walton, Elbert H. (C)

COLUMBUS

Paulson, John M. (B)
Woodward, Herbert (C)

DALLAS

Kennedy, Albert E. (C)

DAYTON

Doyle, Arthur J. (B)
Idle, Clarence (C)
Johnston, Allan C. (B)
Simon, Raymond (C)

DETROIT

Adams, Robert J. (B)
Arlt, Henry O. (B)
Cameron, A. T. (C)
Crofts, Harry G. (B)
Gaenssle, Paul (B)
Hoad, William R. (C)
Johnson, Adolph (B)
Jones, Herbert E. (B)
Klein, Richard F. (B)
Mahon, Russell C. (A)
Mason, Louis (B)
McMacken, J. R. (C)
Meade, W. E. (C)
Myers, Ray (B)
Roberts, S. N. (B)
Simonenko, Alex J. (B)
Smith, Paul (B)
Stilwell, Gale (B)
Waltsgott, William C., Jr. (B)
Warren, Robert E. (B)
Wilamowski, Arthur R. (B)

EAST TEXAS

Belcher, Roy E. (C)
Fields, Thomas L. (B)

HARTFORD

Boyd, Gilbert D. (B)
Ertman, Irvin L. (B)

HOUSTON

Brewer, Carl F. (C)
Fitz, Orville W. (B)
Jones, Robert S. (C)
Ruckman, James R. (B)
Trimble, E. L. (B)
West, John R. (B)

INDIANA

Bauer, James H. (B)
Killinger, George L. (C)
Miller, Ralph (B)
Reiss, Paul R. (B)
Smith, David John (B)
Wilson, Harold R. (B)

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Atleberry, Gene (B)
Netz, Clyde E. (C)
Stillwagon, Clifford H. (B)
Vance, Lloyd F. (C)

LEHIGH VALLEY

Fitzgibbon, Thomas C. (C)

LONG BEACH

Soman, C. R. (C)
Tilton, Julian (B)

LOS ANGELES

Angeloff, Kenneth (B)
Guinn, Albert D. (C)
Harrison, J. R. (B)
Marquez, Henry (B)
Roberts, Bernard S. (B)
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Washburn, Benjamin (B)

Saved at a cost of only 22^{50} ...and back on duty at 1650°F

This Inconel® radiant tube had served 15,000 hours in a pit type gas-fired furnace at temperatures as high as 1650° F.

Then, finally after four years of rugged duty, a break occurred where the tube joined the burner. The rest of the tube was in good shape, so Electric Auto-Lite engineers decided to salvage it rather than purchase a new one.

This was possible because deposits of Inconel welding wire have the same resistance to oxidizing and reducing atmospheres as the parent metal and good strength at high temperatures.

They called on The Industrial Fabricating Co. of Toledo, Ohio to do the job.

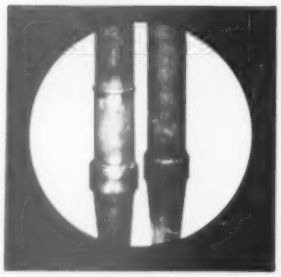
Here's how Industrial proceeded . . .

First, they rebored the old burner casting and inserted a new 8-inch long segment of 3½" O.D. tubing with a wall thickness of .109". Then they joined the new tube segment to the old burner casting with "62" Inconel filler wire. An inert gas shielded process was used to eliminate any possibility of slag entrapment which would weaken the weld.

Finally, they butt welded the new tube section to the other end of the old radiant tube. Now the tube is back in service ready for more long hours of high-temperature duty and the total cost of the salvage job was only $22.50 compared to the substantially higher cost and time required for a new replacement.

This is another case of how an Inco Nickel Alloy welding wire saved an expensive part and helped return it to useful service. It's always good to remember that regardless of the welding method preferred, there is a suitable Inco welding wire or electrode for welding Inco Nickel Alloys. Another thing, too, if you're up against a tough welding problem, Inco's Technical Service is always ready to help you find a solution.

Consult your distributor of Inco Welding Materials for the latest information on their availability.



The Industrial Fabricating Co., of Toledo, was able to save this Inconel radiant tube for Electric Auto-Lite Co., of Cleveland, for only $22.50. The tube was fabricated construction which made the repair feasible. Welder is using a tungsten arc welding torch and "62" Inconel filler wire. Inco's "60's" series of welding wires are especially made for inert gas shielded metal arc welding processes.

Remember, too — it always helps to anticipate your requirements well in advance.

Write today for your free copy of "Inco Welding Materials." It outlines recommended materials for similar and dissimilar joints involving Inco Nickel Alloys.

THE INTERNATIONAL NICKEL COMPANY, INC.
67 Wall Street, New York 5, N. Y.

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Reed, James F. (C)

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Dyble, William (C)
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Peck, Robert (C)
Zettel, Arthur (C)

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Dennis, Richard H. (B)

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Arretz, John F. (B)
Sabino, Peter (C)
Smack, John C. (B)
Tommas, Robert (B)

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Balderson, Harry (C)
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Yeager, Harry (B)

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Stinson, S. Davis (B)

NORTHWEST

Richmann, Leroy C. (C)

NORTHWESTERN PENNSYLVANIA

Lagerstrom, Nils H. (B)
Peelman, R. K. (B)

OKLAHOMA CITY

Fuksa, Laddie Louis (D)
Rorick, Charles E. (C)

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McMullen, Harry W. (C)

PHILADELPHIA

Hoff, Richard L. (B)
Maire, Stephen F. (C)
Stolz, Paul F. (C)
Thomas, Robert W. (C)
Wenner, Edward F. (C)

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Clair, James P. (C)
Krieger, A. N. (B)
Patton, Patrick, J. (C)

PUGET SOUND

Anderson, Alex J. (C)
Brown, W. Clark (C)
Jensen, Elwood K. (C)
Johnson, Clarence A. (C)
Keller, C. H. (B)
Koepp, Walter R. (C)
McLean, H. E. (C)
Shaw, Howard John (C)

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Guisenberry, John N. (B)
King, A. W., Jr. (C)

ROCHESTER

Burger, Melvin J. (C)
Cappellino, Charles R. (C)
Dolley, Benjamin J. (C)
Hofherr, Fred M. (C)
Phelan, Richard L. (C)

SAGINAW VALLEY

Hillman, Louis L. (C)
La Grow, Raymond (B)
Sbordon, Victor G. (C)

ST. LOUIS

Blasiol, Victor J. (B)
Slankard, Ivan J. (C)

SALT LAKE CITY

Bamberger, Clarence, Jr. (B)

SAN FRANCISCO

Gerin, Harry (B)
Sorensen, Lars K. (B)

SYRACUSE

DeHaven, Robert (C)
Earhardt, Chris (C)
Ferguson, Arthur A. (C)
Lohnas, Russell H. (C)
Porter, Glenn G. (C)
Robertson, Robert D. (C)
Yost, Frank J. (C)

TOLEDO

Maney, George (C)

TRI-CITIES

Ahearn, Richard L. (C)
Paetz, Robert (B)

WASHINGTON

Arnaud, Jean (B)

WESTERN MICHIGAN

Baker, John R. (B)
Heiman, Burton (C)
Slack, Frank (C)
Zambroski, Edward (C)

WICHITA

Newcom, S. L. (C)
Smith, Lloyd A. (C)

WORCESTER

Edlin, Merton E. (B)
Helms, Charles L. (C)
Ward, Arthur C. (B)

NOT IN SECTIONS

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INDEX TO ADVERTISERS

Air Reduction ..... Outside back cover
Alloy Rods Company 259
The American Brass Company 257
American Chain and Cable Co. 262
American Manganese Steel Division 263
American Welding Society 264
Ampco Metal, Inc. 265
Fred C. Archer, Inc. 281
Aronson Machine Co. 256
Becker Brothers Carbon Co. 248
The Champion Rivet Co. 258
Crucible Steel Company of America 255
J. W. Dice Company 272
Dockson Corporation 240–241
Eutectic Welding Alloys Corporation 253, 277
General Electric 270, 271
Haynes Stellite Company, a Division of Union Carbide and Carbon Corporation 245
Hobart Brothers Company 199
The International Nickel Company, Inc. 285
Jackson Products ..... Inside back cover
Lapeer Mfg. Co. 248
The Lincoln Electric Company 247
Linde Air Products Company, A Division of Union Carbide and Carbon Corporation 202
P. R. Mallory & Co., Inc. 201
The McKay Company 267
Metal & Thermit Corporation 200
Miller Electric Manufacturing Co. 249
National Cylinder Gas Company 273
Page Steel and Wire Division 262
Pennsylvania Optical Company 251
The Reid-Avery Company 279
The Sight Feed Generator Company 242
Smith Welding Equipment Corporation 266
Square D Company 269
Stulz-Sickles Co. 260
A. O. Smith 243
Sylvania Electric Products, Inc. 283
Tempil° Corporation 244
Tweco Products Company ..... Inside front cover
Union Carbide and Carbon Corporation
Haynes Stellite Company 245
Linde Air Products Co. 202
United States Testing Company, Inc. 261
Victor Equipment Company 204
Welding Fittings Corp. 275
Weldwire Company, Inc. 246
Westinghouse Electric Corporation 280
J. H. Williams & Co. 261

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Supplement to the Welding Journal, March, 1953

Temperature Distribution During Flash Welding of Steel—Part II

Linear flashing patterns are generally not satisfactory. Parabolic flashing conditions have been established for round specimens of three diameters

by E. F. Nippes, W. F. Savage, S. S. Smith, J. J. McCarthy and G. Grotke

Abstract

Previous studies of the effect of linear flashing velocities on the temperature distribution in rectangular sections of AISI 1020 steel were extended by an investigation of very slow linear flashing velocities. This investigation confirmed the fact that linear flashing patterns fail to establish a stable stage-two temperature gradient, and indicated that even with very slow linear velocities, very precise control of the initiation of upset may be required to assure consistent upsetting action.

Studies of the effect of parabolic flashing conditions on the temperature distribution in AISI 1020 steel were made using round specimens of three different diameters. The flashing parameter previously developed to relate the temperature distributions in rectangular steel specimens to the flashing conditions was modified for similar application with round specimens. Comparison of the temperature distribution produced in round and rectangular steel specimens by the same flashing conditions revealed that the shape of the section influenced the temperature distribution.

INTRODUCTION

THE selection of welding conditions for producing a satisfactory flash weld is complicated by the number of variables involved and the interaction which exists between variables. The production of a satisfactory flash weld requires:

1. Proper selection of flashing variables in order to obtain a suitable temperature distribution in the material at the initiation of upset.
2. Selection of suitable upset conditions to insure adequate forging action and removal of all traces of entrapped oxides at the weld interface.

The temperature distribution established during flashing has been previously investigated for the structural aluminum alloys,[1] and a knowledge of the nature of this temperature distribution was found helpful in determining optimum flash welding conditions.[2] A more recent investigation[3] had as its object the study of the effect of flashing variables on the temperature distribution in rectangular steel sections. The results of the latter investigation indicated that:

1. The behavior of the temperature distribution during flashing depends upon the type of platen time-displacement pattern utilized during the flashing operation, the initial clamping distance and the thickness of the section involved.
2. The flashing voltage has no noticeable effect upon the temperature distribution.

Two types of platen-time displacement pattern were studied; a constant velocity platen movement, known as a linear flashing pattern, and a constant rate of acceleration of the platen, known as a parabolic flashing pattern. The results of studies involving these two types of flashing pattern indicated that, with parabolic

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flashing, a stable temperature distribution is obtained early in the flashing cycle and exists unchanged over a considerable range of material burnoff. On the other hand, the linear flashing patterns studied exhibited a continuous change in the temperature distribution throughout the flashing operation. As a result of these studies, a flashing parameter was developed and utilized to predict the stable temperature distributions produced in rectangular steel sections by parabolic flashing.

At the time of the initial investigation, no work had been done on sections other than rectangular, and therefore, additional work now completed, was undertaken involving similar studies for round steel bar stock. This report summarizes the effect of parabolic flashing variables on the temperature distribution in round steel bar stock. In addition, the results of further studies of the temperature distribution in rectangular steel sections flashed at very slow constant velocities have been included in order to extend the range of velocities studied in the previous investigation.

OBJECT AND SCOPE

The object of this investigation was twofold:

1. To evaluate the contribution of flashing variables to the temperature distribution back of the flashing interface for very slow linear flashing patterns with rectangular steel sections.
2. To evaluate the contribution of flashing variables to the temperature distribution back of the flashing interface for parabolic flashing patterns with round steel sections.

MATERIAL

Since the thermal and electrical properties of most constructional steels are not significantly altered by chemical composition,[4] these studies were conducted using AISI 1020 steel, hot-rolled, pickled and oiled. All bar stock was degreased prior to use, and where necessary, excessive scale removed by wire brushing or belt grinding. No special end preparation was utilized other than cutting the specimens to length on an abrasive cut-off wheel and removing the burrs by a light grinding operation.

Three sizes of round bar stock, $^5/_8$, $^3/_4$, and 1 in. nominal diameter, were used in the investigation of the temperature distribution in round bar stock. The end of one sample from each pair of 1-in. diameter rounds was cut at an angle of 2° from perpendicular in order to facilitate starting at the faster rates of acceleration. The investigation of the slow linear flashing patterns was conducted using 0.250 x 2.00-in. rectangular bar stock of the same grade. All specimens were 6 in. long.

EQUIPMENT

Welding Equipment

This investigation was conducted using a Federal 300-kva flash welder modified in this laboratory as described in previous reports.[3,5] Power supply for welding was obtained from a single-phase alternator driven by a synchronous motor as previously described.[3]

Instrumentation

The data for this investigation were obtained using a Consolidated Engineering Corp. 18-channel recording oscillograph.

PROCEDURE

Specimen and Thermocouple Preparation

One specimen of each pair employed in the flashing investigation was prepared to receive thermocouples by drilling 0.052-in. diameter holes at appropriate locations. The holes were positioned relative to one another using a specially constructed jig, and the exact location of each thermocouple hole was determined by radiographic means, as previously described.[3] Chromel-alumel thermocouples, made from 0.010-in. diameter chromel-alumel-duplex wire, were securely welded in position at the bottom of each thermocouple hole, and the output voltages continuously recorded during the flashing operation by means of the 18-channel recording oscillograph.

At least four duplicate runs were made at each set of flashing conditions in order to permit elimination of random errors from the data. With the rectangular samples and the 1-in. diameter rounds, seven thermocouples were employed in each specimen, located approximately 0.1, 0.2, 0.3, 0.4, 0.5, 0.6 and 0.7 in. from the initial flashing interface. Six thermocouples were employed in each sample with the $^5/_8$ and $^3/_4$-in. diameter rounds, however, because of size limitations.

Tables 1 and 2 summarize the welding conditions studied during the course of this investigation. In each case, the specimens were flashed for the indicated distance, and the platen then retracted without any upsetting action. This was done to provide a burnoff distance much greater than necessary in order to study the behavior of the temperature distribution as flashing proceeded.

RESULTS

Treatment of Data

The oscillographic traces obtained from each experimental run provided continuous records of the temperature at each thermocouple location, a continuous record of platen position, and a series of timing lines spaced at 0.01-sec intervals. By means of calibration curves for the individual recording galvanometers, values of the instantaneous temperature as a function of time were then obtained for each thermocouple position. Similarly, values of material burnoff

Table 1—Summary of Conditions Studied with Linear Flashing Patterns, Material AISI 1020 Steel

Section size, in.	*Platen velocity, ips*	*Initial clamping distance, in.*	*Burnoff total, in.*
0.250 x 2.00	0.006	1.50	0.80
0.250 x 2.00	0.016	1.50	0.80
0.250 x 2.00	0.016	1.80	0.80
0.250 x 2.00	0.028	2.78	1.45

Table 2—Summary of Conditions Studied with Parabolic Flashing Patterns, Material AISI 1020 Steel

Diameter of rounds, in.	*Platen acceleration, in./sec.²*	*Initial clamping distance, in.*	*Burnoff total, in.*
1.0	0.0014	1.50	0.8
1.0	0.0014	2.00	0.8
1.0	0.0070	1.50	0.8
1.0	0.0120	1.50	0.8
1.0	0.0120	2.00	0.8
0.75	0.0014	1.50	0.8
0.75	0.0192	1.50	0.8
0.75	0.0200	1.50	0.8
0.75	0.0340	1.50	0.8
0.75	0.0750	1.50	0.8
0.625	0.0042	1.50	0.8
0.625	0.0042	1.80	0.8
0.625	0.0070	1.50	0.8
0.625	0.0192	1.50	0.8
0.625	0.0192	1.80	0.8

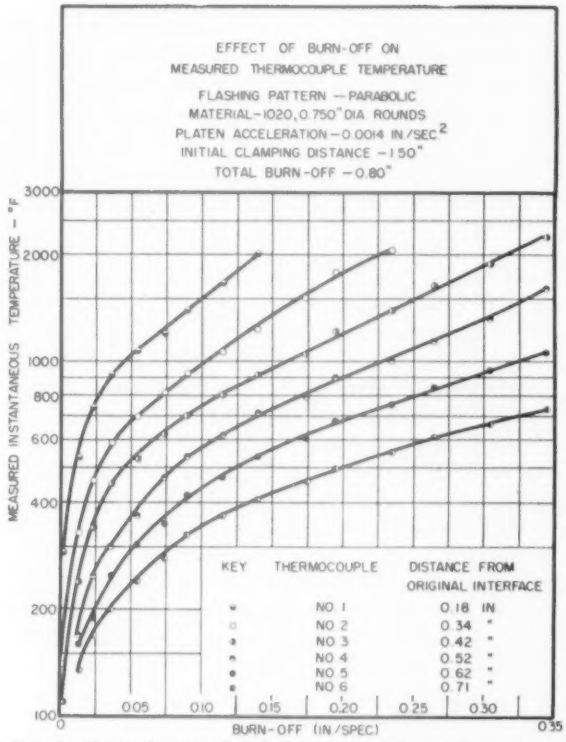

Fig. 1 Typical example of the effect of burnoff on measured thermocouple temperature with a parabolic flashing pattern

as a function of time were obtained from the platen position trace. Eliminating time as a parameter, the instantaneous values of measured temperature were then expressed as a function of material burnoff per specimen, it being assumed that the total burnoff was equally divided between the two specimens. Figure 1 shows a typical plot of measured instantaneous temperature (° F) at each of the six thermocouple positions vs. the per specimen burnoff during flashing. The key at the bottom of Fig. 1 summarizes the location of the thermocouples with reference to the initial flashing interface. The data shown in Fig. 1 were obtained from parabolic flashing of a pair of 0.750-in. diameter steel rounds with a platen acceleration rate of 0.00141 in./sec², an initial clamping distance of 1.50 in. and a total burnoff of 0.80 in. Similar plots were made from data obtained from each of three other duplicate runs as the initial step in determining the temperature distribution for these conditions.

From each set of four such plots, knowing the location of the thermocouples with respect to the flashing interface, it was possible to obtain a graphic summary of the temperature distribution for each combination of flashing variables. Figure 2, obtained from Fig. 1 and its three companion plots, shows how the temperature at each of six different distances from the instantaneous flashing interface depends upon the burnoff. Figure 2 is included as a typical example of a temperature distribution vs. burnoff plot, and will be used to illustrate the method used in constructing such plots from the data.

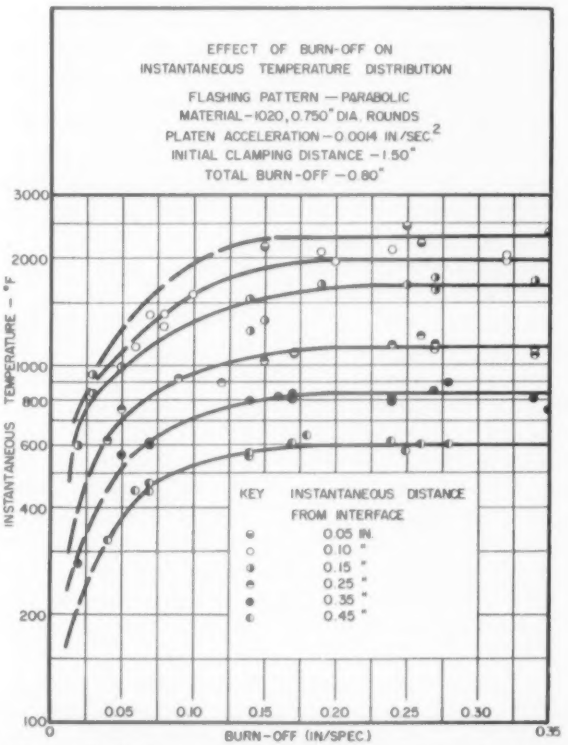

Fig. 2 Typical example of the effect of burnoff on instantaneous temperature distribution with a parabolic flashing pattern

Referring to Fig. 1, it may be seen that the No. 2 thermocouple, originally located 0.34 in. from the initial flashing interface, reached a temperature of 2100° F after 0.24 in. had been removed from the specimen by flashing. After 0.24 in. of burnoff, this thermocouple was located 0.10 in. from the instantaneous position of the flashing interface, and therefore a point will be found in Fig. 2 at 2100° F, for the 0.10-in. position, at 0.24-in. burnoff. Similarly, after 0.32-in. burnoff, the No. 3 thermocouple, originally located 0.42 in. from the initial flashing interface, reached a position 0.10 in. from the instantaneous flashing interface, and indicated a temperature of 2050° F. This information is indicated in Fig. 2 by the point for the 0.10-in. distance, located at 2050° F, for a burnoff of 0.32 in. This process was repeated, and the data obtained were plotted until the family of curves shown in Fig. 2 could be constructed, indicating the influence of the amount of burnoff on the instantaneous temperature at six positions relative to the instantaneous flashing interface. The same technique was employed for each combination of flashing variables studies, and similar plots were obtained. By comparison of these temperature distribution plots, the effect of the flashing variables on the temperature distribution was studied.

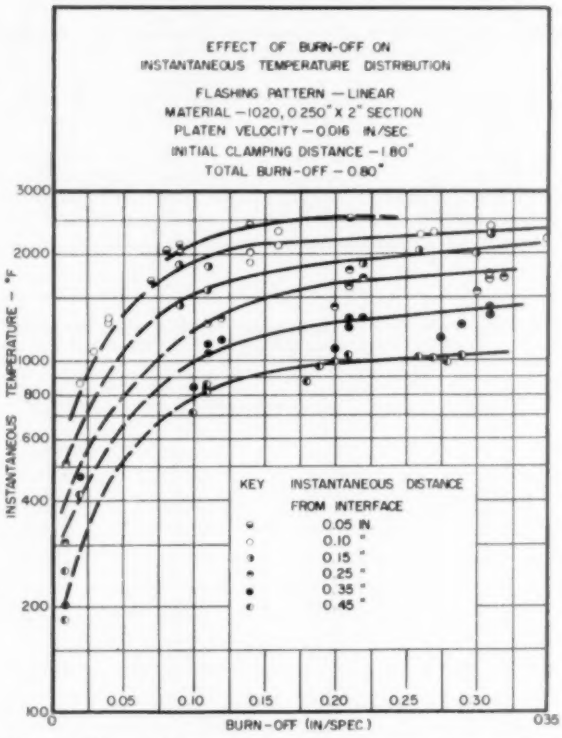

Fig. 3 Effect of burnoff on instantaneous temperature distribution

Results of Linear Flashing Studies

Figures 3 and 4 show the effect of burnoff on the temperature distribution in 0.250-x 2.00-in. samples flashed with a constant platen velocity of 0.016 ips, the initial clamping distance being 1.80 and 1.50 in., respectively. Comparison of these figures reveals that the behavior of the temperature distribution with burnoff is similar for the two cases until approximately 0.20 in. of burnoff has occurred. Both conditions of flashing showed a characteristic rapid rise in temperature along the specimen axis during the initial 0.20 in./spec of flashing, and the temperature distribution at 0.20 in./spec burnoff may be seen to be within 50° F at the indicated distances in the two figures. With continued flashing, however, the shorter distance between the flashing interface and the clamps causes a steeper temperature gradient to be produced in the samples having the shorter initial clamping distance. This is evident from the fact that the temperatures at locations near the flashing interface are nearly the same for equivalent burnoff values in the two figures, whereas the 0.25-, 0.35- and 0.45-in. distance curves in Fig. 4 show a tendency to droop at values of burnoff greater than 0.20 in. Although this effect was not observed in the previous investigation,[3] both the initial clamping distances and the velocities previously studied were considerably greater.

Figure 5 shows the effect of burnoff on the temperature distribution in 0.250-x 2.00-in. specimens flashed with a constant platen velocity of 0.006 ips, with an initial clamping distance of 1.50 in. Since this figure was obtained using the same flashing conditions as were

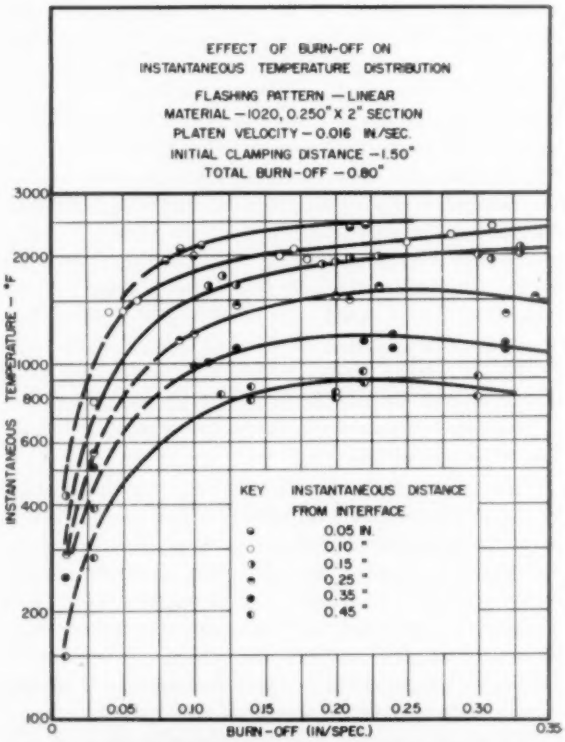

Fig. 4 Effect of burnoff on instantaneous temperature distribution

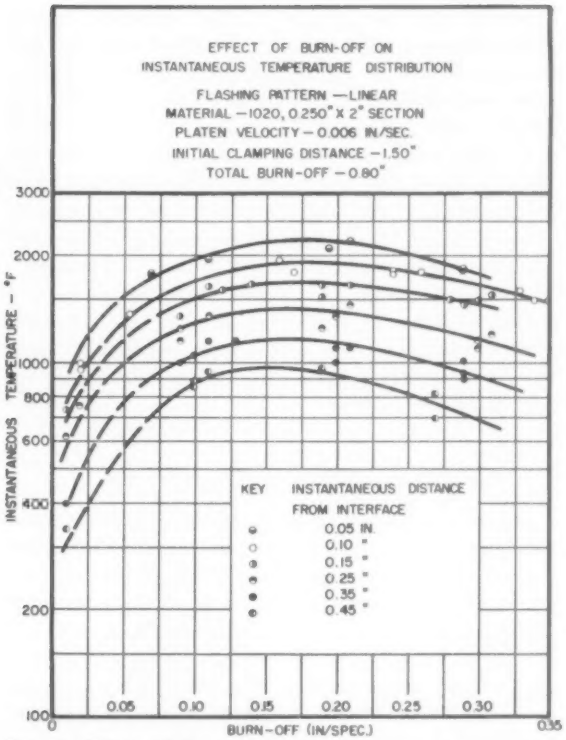

Fig. 5 Effect of burnoff on instantaneous temperature distribution

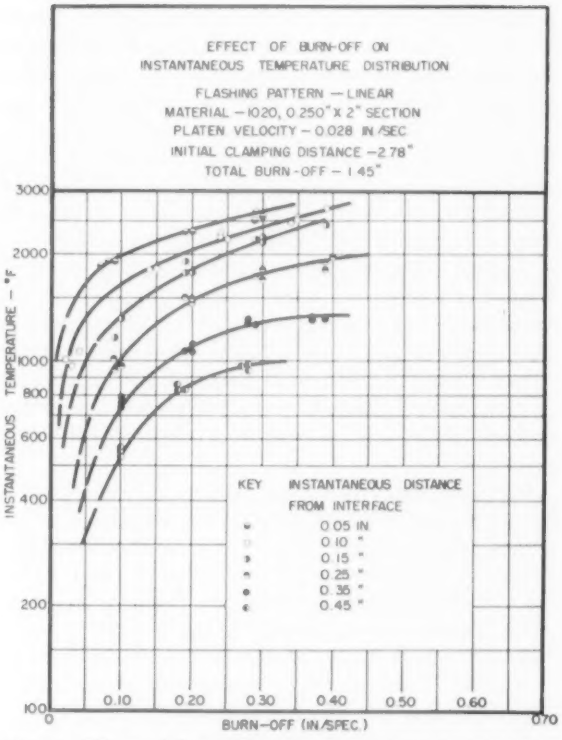

Fig. 6 Effect of burnoff on instantaneous temperature distribution

used for Fig. 4, except for a much slower flashing velocity, the effect of changing the flashing velocity may be readily seen. It is interesting to note that the temperature distribution is extremely unstable with the very slow platen velocity of 0.006 ips used in obtaining Fig. 5. As may be seen by inspection of Fig. 5, the temperature at each position along the specimen axis tends to reach a peak after approximately 0.15 — 0.17 in./spec material burnoff. This is taken as an indication that with very slow flashing velocities, the rate of heat input at the interface is greater than the rate of heat extraction at the clamps only during the initial 0.15 in./spec burnoff. As flashing proceeds, the distance separating the interface from the clamps decreases until the heat flow path becomes short enough to cause heat to be extracted from the material back of the interface faster than it is supplied by the flashing action. This in turn leads to a decline in temperature along the axis of the specimen, as evidenced by the decline in the temperatures at the indicated locations in Fig. 5. In view of the effect of the initial clamping distance demonstrated in Figs. 3 and 4, it is anticipated that decreasing the initial clamping distance would exaggerate this condition further, since the length of the heat flow path from the interface would always be less for the shorter initial clamping distance.

Figure 6 shows the effect of burnoff on the instantaneous temperature distribution in 0.250-x 2.00-in. samples flashed with a platen velocity of 0.028 ips, with an initial clamping distance of 2.78 in. The data shown in this figure support the previous conclusions with regard to the effects of clamping distance and platen velocity on the behavior of the temperature distribution. The longer initial clamping distance of 2.78 in. and the faster flashing velocity of 0.028 ips result in a continuous rise in temperature along the specimen axis at all six locations studied, for burnoff values up to 0.4 in. (In comparing Fig. 6 with Figs. 3, 4 and 5, the change in the burnoff scale should be noted.) The continuous rise in temperature at each of the six distances from the instantaneous interface reflects the influence of both the longer heat flow path, and the increased rate of heat input produced by the longer clamping distance, and faster flashing velocity, respectively.

Linear vs. Parabolic Flashing

In a previous report,[2] the flashing operation was treated as a two-stage process. During the first stage the temperature distribution was found to change continuously as the temperature rose at all points along the specimen axis. During this stage, the heat produced at the flashing interface flows through the specimen toward the water-cooled clamps of the welder, establishing a temperature gradient. The second stage of the flashing period, as previously defined, begins when the temperature gradient reaches a stable value, such that it exists unchanged for a finite amount of burnoff. A third stage could well be defined at this time beginning when the temperature gradient becomes distorted by the influence

of the clamps. All three stages of flashing, as defined above, may be seen by referring to Fig. 5. Stage-one flashing, that is the build-up of the temperature gradient, exists from the start of flashing until approximately 0.15 in./spec material burnoff has occurred. From burnoff values of 0.15 to approximately 0.17 in., the temperature distribution may be considered as essentially stable, that is, the temperature at the six locations treated in Fig. 5 remains essentially unchanged. After approximately 0.17 in./spec material burnoff, however, the temperature at each of the six indicated locations starts to diminish. This distortion of the temperature distribution, or stage-three flashing, becomes more pronounced at positions near the clamps, as may be seen by the steeper negative slope of the curve showing the temperature 0.45 in. from the flashing interface.

Summarizing, for the linear flashing patterns studied, no significant duration of stage-two flashing was observed, there being either no region where a stable temperature gradient existed, or a very short region followed immediately by what has been called stage-three flashing. Stage-three flashing is said to begin when the interface-clamp distance becomes sufficiently small that a distortion of the gradient occurs at a particular flashing velocity.

The behavior of the temperature distribution during parabolic flashing is altogether different. For all platen acceleration rates studied thus far, the duration of stage-one flashing has averaged 0.20 in./spec material burnoff. After 0.20 in./spec burnoff with parabolic flashing, the curves showing instantaneous temperature distribution vs. burnoff remain essentially horizontal until at least 0.35 in./spec burnoff has occurred. Reference to Fig. 2, which is typical of the general behavior of the temperature distribution obtained during parabolic flashing, will corroborate this fact. As was suggested previously,[3] this phenomenon is believed to result from the continual increase in the rate of heat production accompanying parabolic flashing. In other words, although the flashing interface continually approaches the clamps during parabolic flashing, the platen velocity, and, therefore, the rate of heat production is also increasing at a constant rate. The ultimate form of the stable temperature gradient produced during stage-one, and maintained unchanged during stage-two of parabolic flashing, depends in a complex manner upon the platen acceleration rate, the specimen size, and the initial clamping distance.

Parabolic Flashing of Rounds

Since the original studies[3] of the effect of parabolic flashing variables on the temperature distribution were performed with rectangular sections, further work was undertaken using round bar stock in order to study the effect of the shape of the section. Sufficient temperature data were obtained for plotting temperature distribution vs. burnoff curves similar to those shown in Fig. 2 for each combination of flashing variables and bar diameter ($^5/_8$ to $^3/_4$ in.) listed in Table 2.

The characteristic two stage flashing behavior previously observed for rectangular bar stock[3] was found to occur with parabolic flashing of round bar stock. In general, approximately 0.20 in./spec material burnoff was found necessary to establish a stable temperature distribution in round bar stock. Thus it appears that the change from rectangular to round sections does not influence the duration of stage-one flashing. Stage-two flashing, characterized by a temperature distribution which is not altered by material burnoff, was observed for the balance of the flashing operation for all conditions studied. This, too, is in agreement with the behavior previously reported[3] for rectangular specimens with parabolic flashing.

Effect of Initial Clamping Distance

Figure 7, prepared by plotting the stable stage-two temperature distribution as a function of the instantaneous distance from the interface, illustrates the effect of the initial clamping distance upon the stabilized temperature gradient. As may be seen from Fig. 7, with 1.0-in. diameter rounds flashed with a platen acceleration of 0.012 in./sec^2, reducing the initial clamping distance from 2.00 to 1.50 in. caused a slight steepening of the stable temperature gradient. That is, the stable temperature at any distance from the instantaneous position of the flashing interface will be lower for a

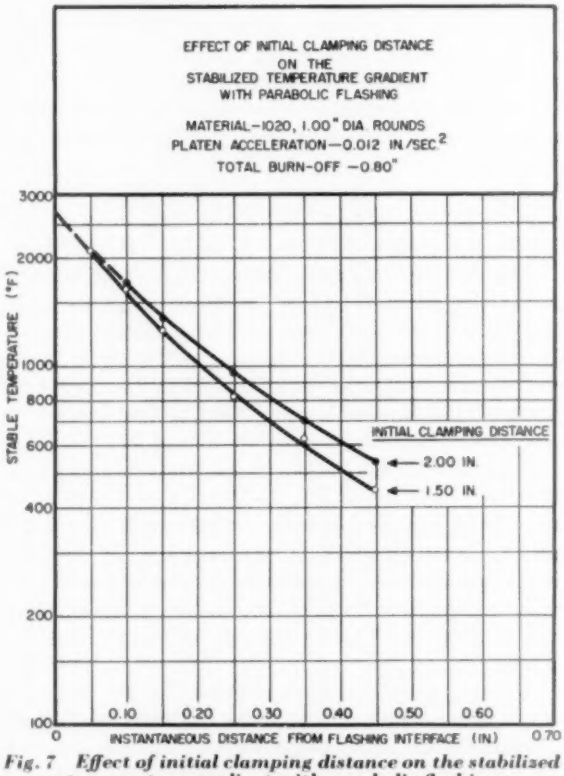

Fig. 7 Effect of initial clamping distance on the stabilized temperature gradient with parabolic flashing

shorter initial clamping distance. For example, referring to Fig. 7, at a distance of 0.30 in. from the flashing interface, the stable temperature was approximately 830° F with a 2.00-in. initial clamping distance, and 700° F with an 1.50-in. initial clamping distance. This effect may be explained by considering the shorter heat-flow path between the interface and the clamps with the shorter initial clamping distance. Since the interface temperature and the clamp temperature are not materially affected by the initial clamping distance, the same temperature difference must be distributed over a shorter distance with the shorter initial clamping distance, and a steeper gradient must therefore result.

Effect of Specimen Diameter

Studies of the effect of section diameter reveal a slight decrease in the stable temperature found at a particular location with respect to the flashing interface when the bar diameter is increased. This is in accord with previous work[3] which showed a similar trend when the thickness of rectangular sections was increased. The quantitative influence of the specimen diameter will become evident later in the report, when the summary curves are presented showing the temperature distribution as a function of an empirical flashing parameter.

Effect of Platen Acceleration

With parabolic flashing, the platen acceleration was found to be the most influential variable affecting the temperature distribution in round bar stock. Figure 8 summarizes the effect of platen acceleration on the temperature distribution for an initial clamping distance of 1.50 in., with 0.625-in. diameter rounds. Inspection of Fig. 8 reveals that the temperature at any given distance from the flashing interface is lower, the greater the platen acceleration. For example, at 0.10 in. from the flashing interface, the stable, stage-two temperature was 2000° F with 0.00141 in./sec² platen acceleration, 1600° F with 0.020, 1350° F with 0.034 and 980° F with 0.075 in./sec² platen acceleration.

Application of the Flashing Parameter

In a previous investigation,[3] an empirical flashing parameter was defined which permitted relating the temperature distributions. Since it was found that increasing section thickness and increasing platen acceleration influenced the temperature distribution in the same manner, whereas increasing the clamping distance has an opposing effect, the original parameter was defined as follows:

$$\text{Flashing parameter} = \frac{\text{Platen acceleration (in./sec}^2) \times \text{section thickness (in.)}}{\text{Initial clamping distance (in.)}}$$

Since the present investigation of the temperature distribution in round bar stock indicated the same relationship between flashing variables, the same form was employed for the flashing parameter. However, the diameter of the round was substituted for the thickness term used previously with rectangular specimens.

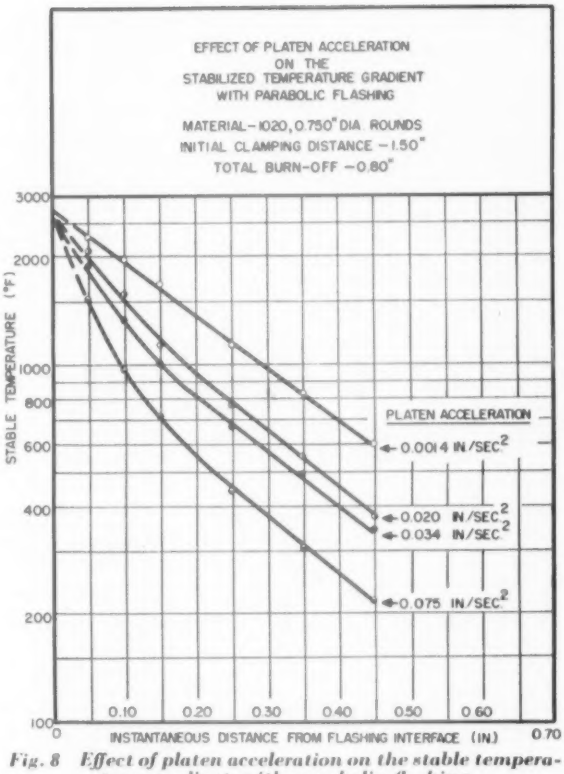

Fig. 8 Effect of platen acceleration on the stable temperature gradient with parabolic flashing

Figure 9 is a summary showing the stable, stage-two temperature data for all parabolic flashing conditions studied plotted as a function of a flashing parameter, defined as follows:

$$\text{Flashing parameter for round bar stock} = \frac{\text{Platen acceleration (in./sec}^2) \times \text{bar diameter (in.)}}{\text{Initial clamping distance (in.)}}$$

The flashing parameter is plotted on a logarithmic scale for convenience, and it should be noted that a single smooth curve showing the stable, stage-two temperature may be drawn for each of the six positions relative to the flashing interface. Table 3 summarizes the conditions studied, and the data plotted in obtaining Fig. 9. It should be noted that all the stable temperature data fit the indicated-position curves, within the limits of experimental error, when plotted as a function of the flashing parameter.

It is interesting to note that, for values of flashing parameter below 0.0020, the temperature distribution appears to be independent of the value of the flashing parameter. In other words, combinations of flashing variables which give a value of flashing parameter between 0.0004 and 0.002, all result in the same stable, stage-two temperature distribution in all three sizes of round bar stock studied. Any combination of flashing

Table 3—Summary of Data Used in Plotting Fig. 9

Platen acceleration, in./sec²	*Specimen diameter, in.*	*Initial clamping distance, in.*	*Flashing parameter*	*Stable, stage-two temperature in ° F found after 0.20 in./spec burnoff at distances, in inches, from instantaneous flashing interface indicated at top*					
				0.05	*0.10*	*0.15*	*0.25*	*0.35*	*0.45*
0.0042	0.625	1.50	0.00176	2300	2000	1600	1150	810	620
0.0070	0.625	1.50	0.00292	2300	1900	1530	1125	760	575
0.0192	0.625	1.50	0.00800	2175	1660	1270	850	680	480
0.0042	0.625	1.80	0.00146	2300	2000	1650	1150	840	580
0.0192	0.625	1.80	0.00666	2250	1700	1350	950	700	520
0.00141	0.750	1.50	0.00070	2300	2000	1700	1140	850	610
0.0192	0.750	1.50	0.0096	2125	1600	1200	840	590	430
0.020	0.750	1.50	0.0100	2100	1600	1150	780	560	380
0.0340	0.750	1.50	0.0170	1900	1350	1020	680	500	350
0.0750	0.750	1.50	0.0376	1550	980	720	450	310	220
0.00141	1.00	1.50	0.00094	2300	2000	1600	1100	780	640
0.0070	1.00	1.50	0.0046	2250	1800	1450	1050	790	580
0.0120	1.00	1.50	0.0080	2100	1650	1250	820	630	450
0.00141	1.00	2.00	0.0007	2300	2000	1600	1150	880	650
0.0120	1.00	2.00	0.0060	1700	1700	1350	950	700	540

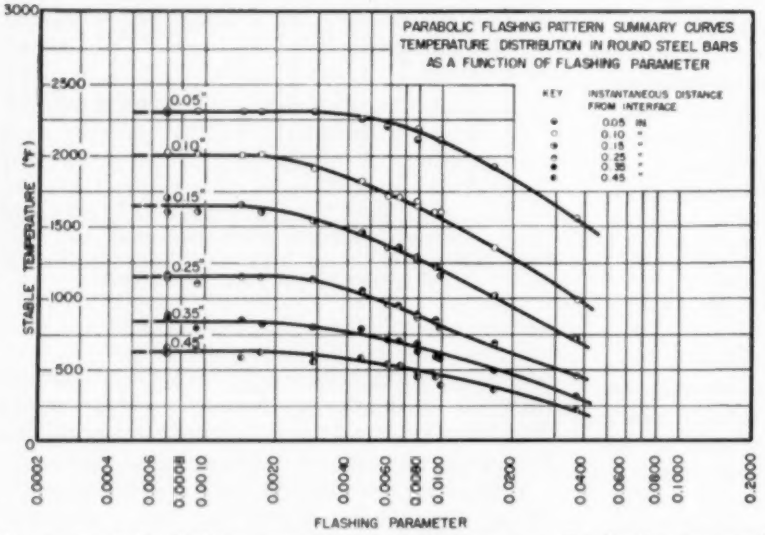

Fig. 9 Parabolic flashing summary curves—temperature distribution in round steel bars as a function of flashing parameter

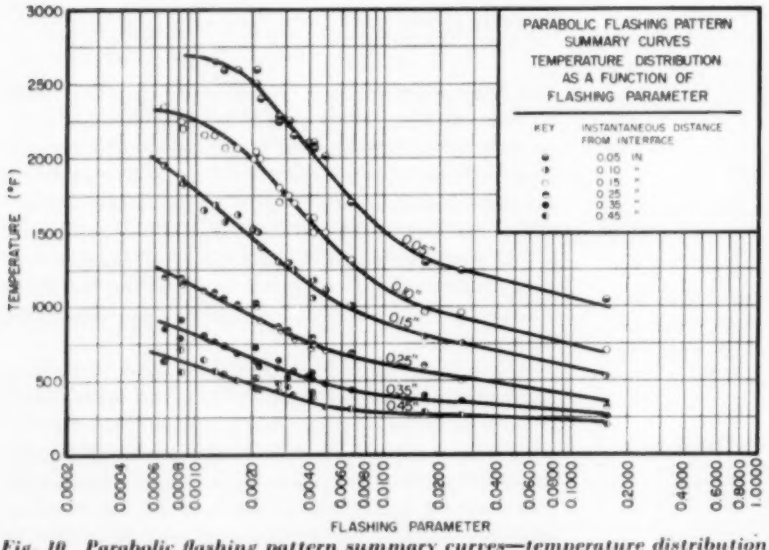

Fig. 10 Parabolic flashing pattern summary curves—temperature distribution as a function of flashing parameter for rectangular steel sections

variables giving a value of the parameter greater than 0.002 tends to produce a steeper stable temperature gradient, however, and the larger the flashing parameter, the steeper is the stable temperature gradient.

From the definition of the flashing parameter, it may be seen that if one of the three flashing variables is fixed, the value of the flashing parameter and, therefore, the temperature distribution may be varied by proper selection of the other two variables. For example, the combinations, 0.625-in. diameter bar, 1.50-in. initial clamping distance, with 0.0192 in./sec² platen acceleration; and 1.0-in. diameter bar, 1.50-in. initial clamping distance, with 0.0192 in./sec² platen acceleration, both result in a flashing parameter of 0.008. By reference to Table 3, it may be seen that the temperature distributions are within the limits of experimental error for these two sets of conditions.

Figure 10, taken from a previous report[2], shows a similar summary curve for parabolic flashing of rectangular sections. Although the influence of the flashing variables on the temperature distribution is similar to that shown in Fig. 9, the agreement between temperature distributions produced in round and rectangular bars is not quantitative. For example, in both round and rectangular stock, a flashing parameter of 0.020 provides a steeper temperature gradient than a flashing parameter of 0.002, but, the tem-

perature gradient produced in round stock differs from that produced in rectangular stock by conditions yielding the same flashing parameter. This may be seen by comparison of the temperature distributions for round and for rectangular bar stock at comparable values of parameter in Figs. 9 and 10. For example, for flashing conditions producing a parameter of 0.020, the stable, stage-two temperature distribution in round bar stock may be determined from Fig. 9 to be: 1820° F at 0.05 in. from the flashing interface, 1260° F at 0.10 in., 930° F at 0.15 in., 610° F at 0.25 in., 450° F at 0.35 in. and 330° F at 0.45 in. In rectangular bar stock, for flashing conditions yielding the same value of parameter, 0.020, the stable stage-two temperature distribution may be found in Fig. 10 to be: 1280° F at 0.05 in. from the flashing interface, 950° F at 0.10 in., 730° F at 0.15 in., 550° F at 0.25 in., 360° F at 0.35 in. and 260° F at 0.45 in. In other words, the rectangular specimens exhibited a steeper temperature gradient than the round specimens for flashing conditions yielding a flashing parameter value of 0.020. Further comparison of Figs. 9 and 10 reveals that with low values of the flashing parameter, below 0.003 the temperature gradient in the rectangular sections is also steeper than that found in round sections, but the temperature at locations near the interface tends to be higher for rectangular sections. Furthermore, the temperature at locations near the clamping jaws tends to be lower in the rectangular stock than in the round stock flashed with conditions yielding the same flashing parameter throughout the entire range of flashing parameters studied. It is believed that this results from the different cross-sectional area to surface area ratio for the two section shapes. The rectangular sample, having a higher surface area for a given cross-sectional area, can more readily transmit its heat to the clamping jaws, thus, a steeper temperature gradient could be expected in rectangular sections. In other words, for the same cross-sectional area, and therefore the same longitudinal heat flow path within the specimen, a rectangular specimen has a larger surface area from which heat may escape, thus steepening the temperature gradient.

At present, no mathematical interpretation has been arrived at which will permit correlating the temperature distribution in round and rectangular specimens. It therefore appears necessary to utilize two families of curves such as shown in Figs. 9 and 10, one for rounds, and one for rectangular sections, and to determine the temperature distribution from the appropriate figure.

In a previous report,[3] examples were cited illustrating the use of the curves shown in Fig. 10 for determining the expected stable temperature distribution in rectangular sections. The same principles hold in utilizing the curves of Fig. 9 to predict the stable temperature distribution in round specimens. For example, suppose, a 1.0-in. diameter round is to be flashed with a platen acceleration of 0.010 in./sec^2 and an initial clamping distance of 1.3 in., the results of this investigation indicate that approximately 0.2 in. must be burned off each specimen before a stable, stage-two temperature distribution is attained, regardless of specimen size or shape. Therefore, let us assume that somewhat more than 0.2 in./spec burnoff is employed, say 0.3 in./spec to be on the safe side, and it is desired to know how much material will be above the forging temperature (1300° F) as a result of this flashing action. The first step would be to calculate a flashing parameter, in this case:

$$\text{Flashing parameter} = \frac{0.010\ (\text{in./sec}^2) \times 1.0\ (\text{in. diam})}{1.3\ (\text{in. initial clamping distance})} = \frac{0.010}{1.3} = 0.007$$

Next referring to Fig. 9, the value of the flashing parameter (0.007) would be located on the abscissa. The stable, stage-two temperature distribution could then be obtained from the intercepts of a vertical line, erected at the flashing parameter value of 0.007, with the curves representing the stable temperature at each of the six locations. Thus, it may be seen that approximately 0.15 in. of material would be above the arbitrarily chosen forging temperature of 1300° F for the flashing conditions listed above. By means of this same procedure, a similar determination of the temperature distribution could be accomplished for other combinations of flashing conditions.

CONCLUSIONS

1. Slow linear flashing velocities of 0.006, 0.016 and 0.028 ips were studied using 0.250- x 2.00-in. rectangular sections of AISI 1020 steel.

2. All linear flashing conditions exhibited an initial, or stage-one temperature distribution behavior while a temperature gradient was being established. During stage-one flashing, the temperature was observed to rise continuously along the longitudinal axis of the specimen.

3. No appreciable duration of stable, or stage-two, temperature distribution was observed with any of the slow-linear flashing patterns studied.

4. With the slower linear velocities, and with shorter initial clamping distances, a third-stage temperature distribution behavior may be observed. During stage-three, heat is extracted at the clamps more rapidly than it is produced at the interface, and the temperature gradient steepens continuously as burnoff proceeds.

5. Since no appreciable duration of a stable, stage-two temperature distribution was found with the slow linear flashing patterns studied, the initiation of upset would have to be very accurately controlled in order to assure consistent duplication of a particular temperature distribution at the instant of upset.

6. Various parabolic flashing conditions were studied, and the temperature distributions resulting in 1.00-, 0.750- and 0.625 -in. diameter rounds of AISI 1020 steel were measured.

7. The interval of burnoff required to establish a stable, stage-two temperature distribution in rounds was found to be approximately 0.20-in. burnoff per specimen

with parabolic flashing. This is in agreement with the value of 0.2-in. burnoff per specimen previously reported for rectangular specimens, and was not appreciably affected by the size of the section being flashed.

8. Increasing the platen acceleration rate with parabolic flashing was found to produce a steeper temperature gradient in round specimens. This is in agreement with the previous findings for rectangular specimens.

9. Reducing the initial clamping distance was found to produce a steeper temperature gradient in rounds, as had been previously shown for rectangular sections.

10. Increasing the diameter of the specimen was found to produce a slightly steeper temperature gradient.

11. An empirical flashing parameter was developed, defined by the equation,

$$\text{Flashing parameter} = \frac{\text{Platen acceleration (in./sec}^2\text{)} \times \text{diam of round (in.)}}{\text{Initial clamping distance (in.)}}$$

which permitted comparison of various flashing conditions in terms of the stable, stage-two temperature distributions produced.

12. A summary plot was produced, consisting of a family of curves showing the stable, stage-two distribution in rounds as a function of the parabolic flashing conditions.

13. Comparison of the summary plot for rounds with a similar plot for rectangular steel sections revealed that the shape of the specimen influences the temperature distribution.

14. No satisfactory method has been obtained permitting correlation of the effect of flashing variables on the temperature distribution in round and rectangular specimens. However, by use of the appropriate summary curves, the temperature distribution in both round and rectangular sections may be predicted from the flashing variables.

15. An example of the use of the summary curves is included in the text.

ACKNOWLEDGMENTS

The authors wish to acknowledge the financial support provided this investigation by the Air Research and Development Command, Wright-Patterson Air Force Base, Ohio, under Contract No. AF18 (600)-71.

They also wish to acknowledge the advice and suggestions received from the Flash Welding Subcommittee of the Welding Research Council.

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Notch Impact Tests of Weld Metal at Low Temperatures

by M. Lefèvre and J. Lemoine

Summary

THE transition temperature based on a criterion of minimum energy (5.5 mkg/cm² or 20 ft-lb) with a round notch Charpy specimen has been determined for weld metal deposited by four different covered electrodes. For rutile, neutral and basic coverings the transition temperatures are equivalent to, and sometimes lower than, basic Bessemer steel. The order of merit with respect to transition temperature is the same with round- and sharp-notched specimens. Ferritic grain size has an important effect on transition temperature of weld metal. Nonuniform structure accounts for the rather large scatter of impact results at low temperatures, particularly for welds deposited at low interpass temperatures. For best notch impact results in multiple pass welds at low temperatures, preheating is recommended.

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Abstract of "Essais de résilience à basse température," published in *Arcos*, No. 125, 3171–3189 (April 1952). Abstracted by Dr. G. E. Claussen.

Specimens

The impact specimens were cut from butt welds (70 deg included angle, 0.20-in. root spacing) in plates 4 x 8 x 0.59 in. Backing bars were 0.79 x 0.20 in. Welding was performed with alternating current with $^5/_{32}$-in. electrodes of four commercial types: Stabilend and Exelend (neutral coatings), Navalend (rutile-cellulose coating) and Ductilend 55 (basic coating). The basic

electrode was welded also on reverse polarity. The interpass temperature was 480—570° F measured with a thermocouple 0.20 in. from the upper edge of the groove.

Three types of specimens were used, Fig. 1. The Charpy specimen with Izod notch 2 mm deep frequently is used in America, but we decided to use a sharp notch 5 mm deep for better comparison with the 5-mm round notch. Impact tests were made at −103, −76, −40, −4, +32 and +68° F (−75, −60, −40, −20, 0 and +20° C), except for the Schnadt specimens for which −40° was sufficient. Three specimens were broken at each temperature. Specimens for test below −4° F were broken within 6 sec. after removal from the cooling bath.

Results

Average results, excluding abnormal values, are plotted in Figs. 2 to 4. The results for Navalend and Exelend were similar in trend to, but higher than, those for Stabilend. The absence of an abrupt transition, such as some steels exhibit, is a safety factor for weld metal. Since the electrodes can be classified in the same order with both the round-notched and sharp-notched specimens, the round-notched specimen was used in all further tests to be described. The Schnadt specimen gave results that were at variance with experience. With all three types of specimens, fractures tended to be fibrous at the higher temperatures, and brittle at the lower temperatures. At intermediate temperatures fractures were partly brittle, partly fibrous.

We have considered the many proposals in the literature for defining transition temperature and have decided to adopt the 20 ft-lb minimum proposed by Rinebolt,[1] corresponding to 5.5 mkg/cm². This value fits our results very well.

Effect of Structure

At the lower temperatures there was occasionally an abnormally low impact result. For example, the basic electrode at −40° and reverse polarity gave 10.50, 10.70 and 1.98 mkg/cm². We cannot attribute the low value to scatter accompanying transition because at −103° F the results were over 7 mkg/cm². The cause seems to lie in the coarse grain structure of a few specimens, as suggested by the work of Hodge.[2] Impact tests therefore were made on Stabilend and Ductilend weld metal after two heat treatments: (*a*) 1 hr at 1610° F followed by rapid air cooling, to produce fine grain, (*b*) 1 hr at 2010° F followed by furnace cooling to produce coarse grain. The resulting ASTM grain sizes were over 8 for (*a*) and 6 for (*b*).

The results, Figs. 5 and 6, show the high impact value of fine grain structure, but show that the nature of the structure also is important. For the Stabilend electrode the as-welded structure is superior to the annealed, whereas for the Ductilend electrode the reverse is true.

Effect of Interpass Temperature

Micrographic examination revealed more cast structure at the lower interpass temperatures in Ductilend

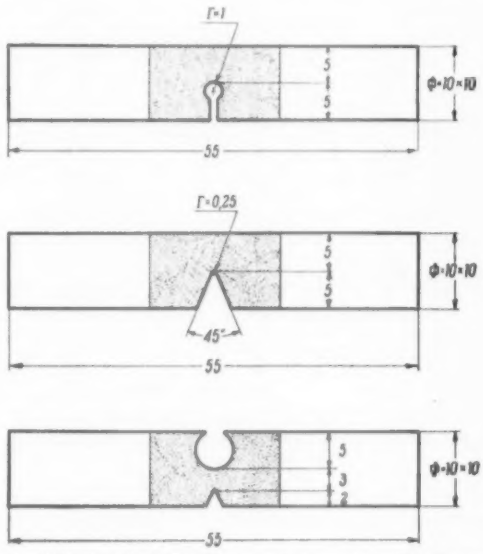

Fig. 1 (a) Standard Charpy specimen. (b) Charpy specimen with Izod notch. (c) Schnadt specimen

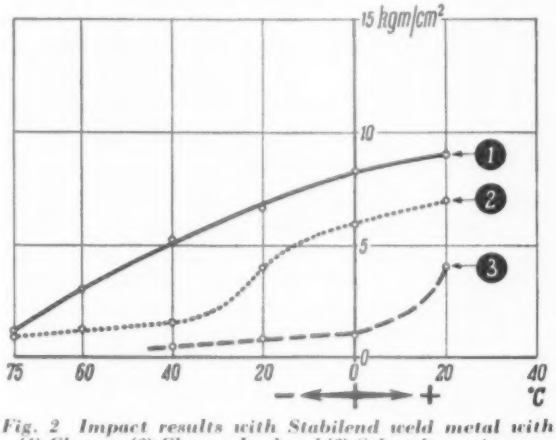

Fig. 2 Impact results with Stabilend weld metal with (1) Charpy, (2) Charpy-Izod and (3) Schnadt specimens

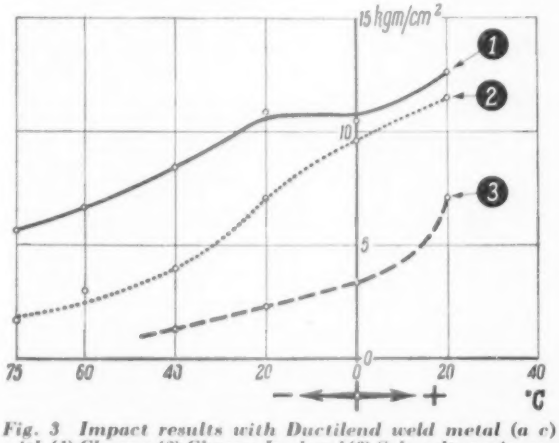

Fig. 3 Impact results with Ductilend weld metal (a c) with (1) Charpy, (2) Charpy-Izod and (3) Schnadt specimens

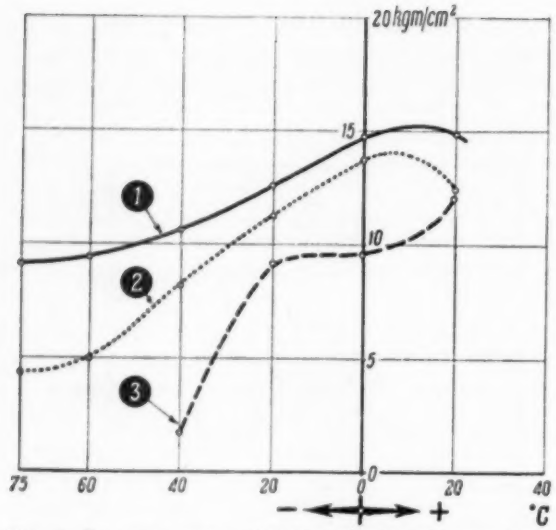

Fig. 4 Impact results with Ductilend weld metal (d-c reverse polarity) with (1) Charpy, (2) Charpy-Izod and (3) Schnadt specimens

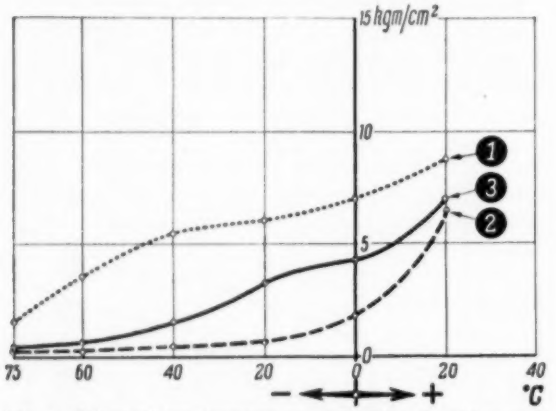

Fig. 5 Effect of heat treatment on Stabilend weld metal—(1) fine grain, (2) coarse grain, (3) as-welded

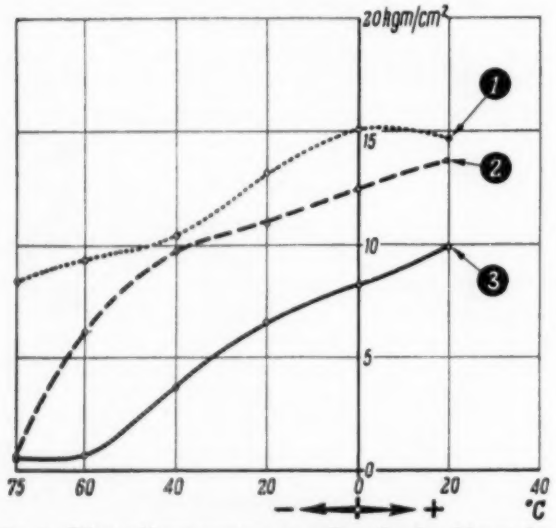

Fig. 6 Effect of heat treatment on Ductilend weld metal—(1) fine grain, (2) coarse grain, (3) as-welded

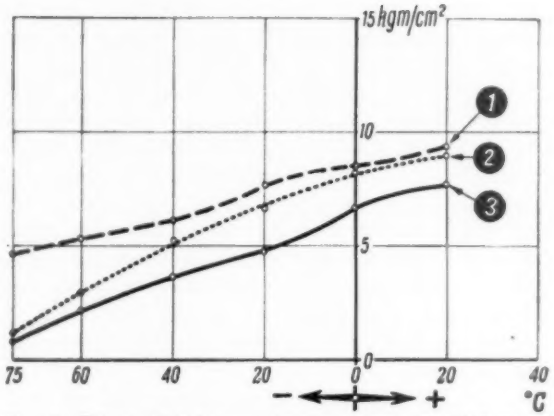

Fig. 7 Effect of interpass temperature—(1) 750° F, (2) 525° F, (3) 212° F)—on Stabilend weld metal. There were several abnormally low values at 212 and 525° F, but none at 750° F.

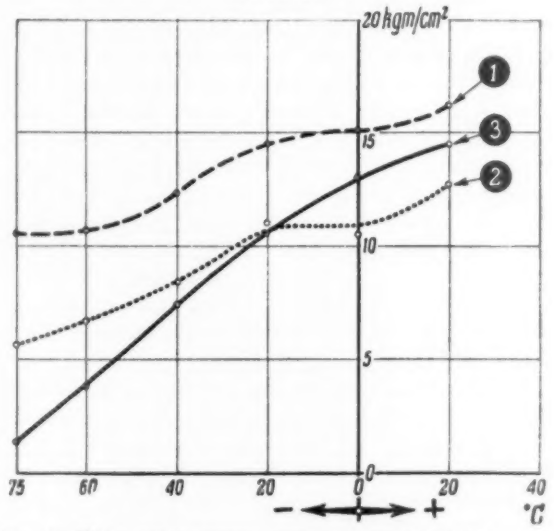

Fig. 8 Effect of interpass temperature—(1) 750° F, (2) 525° F, (3) 212° F)—on Ductilend weld metal. There were several abnormally low impact values among the specimens welded at 212 and 525° F, but none among those welded at 750° F, which eliminated any areas of unrefined weld metal, Table 1

than in Stabilend, Table 1. The former is a "cold" electrode, whereas the latter is "hot." The more frequent occurrence of abnormally low impact values with the cold electrodes thus is explained. The results in Figs. 7 and 8 confirm this explanation. If preheating is carried too far beyond 750° F, the weld metal cools too slowly from a high temperature and the grain size is coarsened again.

Table 1—Proportion of Cast, Unrefined Structure in Per Cent for Three Interpass Temperatures

	Interpass Temperature, ° F		
Electrode	*212*	*525*	*750*
Stabilend	7.5	1-2	0
Ductilend	17.5	10	0

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The Role of Weld Metal Area in Welding Hardenable Steels

Studies of the fundamental relationships of the various factors affecting the base metal heat-affected zone in hardenable steels

by C. R. McKinsey and J. F. Collins

INTRODUCTION

AS WELDING processes and techniques have been developed and improved over the years, the field of application of welding has expanded to its present position, wherein practically all metals can be joined by one or more welding methods. Naturally, as a process expands, new problems are encountered which, at times, may seem insurmountable. However, these problems are eventually overcome by advances in technology, and further growth takes place. Such has been the case with the welding of hardenable steels. The initial major difficulties with cracking, joint strength and the like have been overcome to a large extent, and hardenable steels are being joined successfully by a number of welding methods. However, it is always desirable to seek ways of improving present techniques, and there are certainly regions in this field where increased knowledge of fundamental relationships should lead to improved weld quality. The heat-affected zone* is an example.

It is rather ironic that the same characteristics which make hardenable steels so useful are the ones which contribute to difficulties in welding. These steels derive their excellent combination of strength and ductility from their ability to form substantially 100% martensite upon cooling from a point above the upper transformation temperature at a finite (and practicable) cooling rate. The slower the cooling rate at which this martensitic structure can be obtained, the greater is the so-called hardenability of the steel. This newly formed martensite is extremely hard and brittle, the actual hardness depending upon the carbon content. For this reason, steel is almost never used in the as-quenched condition. Instead, it is reheated to a suitable temperature below the lower transformation temperature and held for an appropriate length of time. This tempering action reduces the hardness and tensile strength but increases the ductility, thus making the steel more suitable for use. The amount of reduction in hardness and in tensile strength, and the corresponding increase in ductility, depend mainly on the temperature at which the steel is tempered.

Because of its lack of ductility, untempered martensite is very susceptible to cracking, either because of external stresses or from internal stresses introduced during transformation. The role of hydrogen in base metal cracking has been reported by a number of investigators and the adverse effect of this element is well known. However, cracking may occur even with welding processes such as shielded-inert-gas-metal arc welding (sigma welding) and Unionmelt† submerged melt welding in which hydrogen is not a significant factor under normal conditions. The structural volume increase during the martensite transformation is opposed by the surrounding mass of metal and the natural thermal shrinkage as the steel cools, thus introducing internal stresses which are sufficient to cause cracking under some conditions. Since the crack sensitivity is roughly proportional to the hardness and hardness is dependent upon the carbon content, high-carbon steels are normally more prone to cracking than low-carbon steels.

In the heat-affected zone of a weld, austenite is formed during heating and transforms during cooling. The transformation product depends on the hardenability of the steel and the cooling rate. If the steel is hardenable, a considerable amount of martensite may be formed in the heat-affected zone. Under adverse conditions, cracking may take place.

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* In this paper, the heat-affected zone is considered to comprise the portion of the base metal next to the weld which is heated to a temperature above the lower transformation temperature but below the melting point of the material.

† The term "Unionmelt" is a registered trademark of Union Carbide and Carbon Corp.

Preheat and postheat treatments have been used successfully to overcome cracking difficulties, and information has been published regarding proper temperatures for use with various steels.[1] Also, special techniques have been devised for reducing cracking tendencies, such as the cladding or "buttering" technique.[2] However, some structures are designed for such severe operating conditions that the mechanical properties of the heat-affected zone must be exceptionally good, and mere absence of cracking is not insurance that suitable properties have been obtained. For even if cracking is avoided, the heat-affected zone may contain relatively hard, brittle areas which would be undesirable in the finished product. Or, conceivably, the heat-affected zone may be so soft and weak that the joint efficiency would be low.

Thus, the problem confronting welding fabricators is a twofold one. First, cracking must be avoided, and second, the resulting weldment must have adequate joint efficiency to meet service requirements. It was the purpose of this investigation to consider some of the factors that affect the properties of the heat-affected zone and the manner in which they are fundamentally related. The data are not sufficient in quantity to permit unqualified conclusions to be drawn but the authors hope that the results will contribute toward a better understanding of the problems involved.

A discussion of weld metal properties is beyond the scope of this paper. All the work was confined to automatic welding processes because of the uniformity and reproducibility of welds made with these techniques.

FUNDAMENTAL CONCEPTS

There has been considerable disagreement concerning the correlation of heat-affected zone properties with tests utilizing conventional heating and cooling methods such as the end-quench hardenability test.[3, 4, 5] Present consensus seems to be that this correlation, if it exists, is not well defined. Therefore, data from actual welds were used in this investigation.

In welding, the deposit is cooled primarily by the conduction of heat through the base metal. For a given plate thickness and a given type of weld, the cooling rate would depend, to a considerable extent, on the total amount of heat to be removed. In other words, the cooling rate is inversely proportional to the heat input, other factors being equal.

Since the maximum hardness in the heat-affected zone of a given steel depends on the cooling rate, it should be possible to correlate maximum hardness with heat input in arc welding. An extensive weldability investigation[3] utilized the concept that the effective heat input was directly related to the arc energy, which could be calculated from the current, voltage and travel speed. However, it has since been proposed that arc energy is not necessarily an accurate measure of effective heat input because the efficiency is not constant over a wide range of welding conditions.[4, 6] One measure of effective heat input is the weld metal area, since this represents the total amount of metal which has been heated to the molten state and retained in the weld. It is insignificant whether the majority of the weld deposit is composed of melted base metal or melted welding rod, provided their heat capacities are similar; the effect on cooling rate would be the same. Therefore, since the maximum hardness in the heat-affected zone is a function of cooling rate, it should be possible to establish a relationship between weld metal area and maximum hardness, and this relationship has been shown for a number of steels by Jackson and Goodwin.[4]

Notch toughness is an essential property in structures which are subjected to shock loading of any sort, and it is important that the heat-affected zone does not contain a notch-sensitive region which would lower the utility of an otherwise satisfactory weldment. The relationship between hardness and notch toughness is apparently quite complex, although both are dependent on the microstructure. It is generally recognized that mixed microstructures containing excessive amounts of either untempered martensite or ferrite will be more notch sensitive than structures which are predominantly lower bainite or tempered martensite. Since a relationship apparently exists between weld metal area and maximum hardness in the heat-affected zone, there is almost certainly a relationship between weld metal area and microstructure in the same zone. Therefore, it is logical to assume that a relationship exists between weld metal area and notch toughness of the heat-affected zone. However, it is necessary to determine whether significant trends can be detected in this relationship with laboratory tests, and whether the results of the laboratory tests can be translated to service performance of welded structures.

MATERIALS AND TECHNIQUES

Two steels were used in this investigation, a boron treated manganese-molybdenum steel and a nickel-chromium-molybdenum steel, both in the form of 1-in. thick plates. These materials had been water quenched and tempered to hardness values of 340 and 260 Brinell, respectively. The end-quench hardenability curves in Fig. 1 show that the manganese-molybdenum steel had the higher hardenability when quenched from 900° C.

Both sigma welding and Unionmelt welding were used during this investigation. Since only the properties of the heat-affected zone were of interest, the weld metal composition was not important, and a commercial low-carbon steel rod was used.

EFFECT OF WELD METAL AREA ON HARDNESS

A series of bead-on-plate welds was made on both

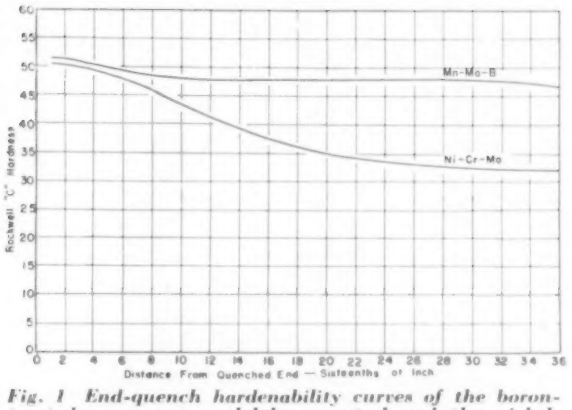

Fig. 1 End-quench hardenability curves of the boron-treated manganese-molybdenum steel and the nickel-chromium-molybdenum steel. Quenched from 900° C

steels, using the sigma process with argon shielding gas. Preheat was not used. Current and travel speed were adjusted so that a variation in weld metal area from about 0.02 to 0.20 sq in. was obtained among the several beads. Since the actual welding conditions are not pertinent to the results, they are not listed.

The weld beads were sectioned, and enlarged reproductions were made of the weld zone. The weld metal area was measured graphically from these reproductions. Diamond pyramid hardness surveys were made across the heat-affected zone at the root of the weld, using a Vickers Hardness tester and a 10-kg load. Readings were taken at intervals of 0.015 to 0.020 in. The maximum hardness of each heat-affected zone was determined by averaging the peak values obtained in each survey. The maximum hardness was found in the coarse-grained area adjacent to the weld. Curves showing the relationship of weld metal area to maximum hardness were obtained from each steel, and are shown in Fig. 2.

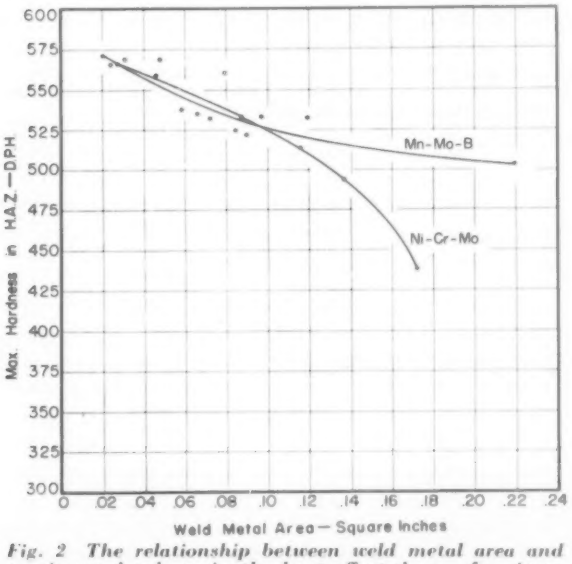

Fig. 2 The relationship between weld metal area and maximum hardness in the heat-affected zone for sigma bead welds

As shown by the curves, the maximum hardness in the heat-affected zone decreased with increasing weld metal area. This trend was more pronounced with the nickel-chromium-molybdenum steel. It may be noted that the curves are somewhat similar in shape to the end-quench hardenability curves in Fig. 1. This was expected, since both curves essentially relate hardness to cooling rate.

In order to investigate the effect of multipass welding, a second bead having a weld metal area of about 0.03 sq in. was deposited on top of each of the original beads (0.02 to 0.20 sq in.) in both steels, and this was repeated with a second bead having a weld metal area of about 0.09 sq in. These tests were made to determine the range of bead sizes in which the heat-affected zone would be appreciably softened by each second bead. These two-pass welds were sectioned, and the new maximum hardness of the heat-affected zone of the original beads was determined as before.

For both steels, the data showed that the size of the second bead relative to the first bead was quite important. If the second bead was too large with respect to the first bead, all or part of the original heat-affected zone was obliterated and replaced by the new heat-affected zone of the second bead. Similarly, if the second bead was relatively too small, its effect on the heat-affected zone at the root of the first bead was negligible. However, if the second bead was approximately the same size as the first bead, the maximum hardness of the heat-affected zone at the root of the original bead was appreciably reduced. These results are illustrated in Figs. 3 and 4, in which the solid lines denote the range of the effective tempering action for each second bead. The original hardness values for the untempered single beads are included for comparison.

In order to further explore the relationship between weld metal area and heat-affected zone properties, a series of welds were made in the manganese-molybdenum steel with the Unionmelt process. These differed from the sigma welds as they were made in beveled plate, thus more closely approximating thermal conditions existing in actual butt welds. The bevel preparation was similar to that recommended for double-bevel welds in 1-in. thick steel. However, only half the plate thickness was beveled; i.e., grooves having a total included angle of 70° and a root spacing of $^1/_8$ in. were machined to a depth of $^1/_2$ in. in the 1-in. thick plate.

Single-pass welds were deposited in these grooves with the weld metal area varying from 0.08 to 0.40 sq in. Preheat was not used. The welds were sectioned, and the weld metal area and maximum hardness in the heat-affected zone were determined in the same manner as with the sigma beads.

The curve of weld metal area vs. maximum hardness is shown in Fig. 5, along with the curve for the sigma bead welds in the same steel. In addition, data from four sigma welds, made in grooves similar to the

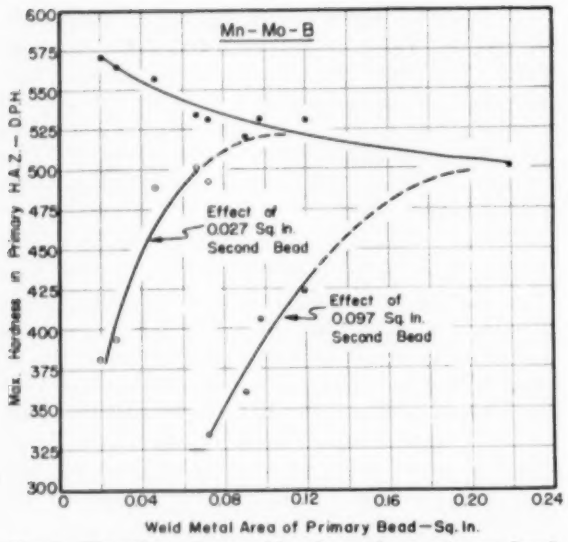
Mn - Mo - B
Max. Hardness in Primary H.A.Z. - D.P.H.
Effect of 0.027 Sq. In. Second Bead
Effect of 0.097 Sq. In. Second Bead
Weld Metal Area of Primary Bead — Sq. In.

Fig. 3 The effect of second beads on the maximum hardness in the heat-affected zone of sigma bead welds in the boron-treated manganese-molybdenum plate

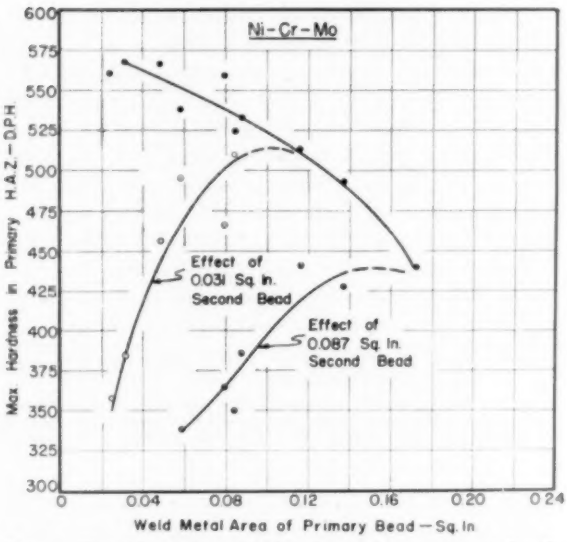
Ni - Cr - Mo
Max. Hardness in Primary H.A.Z. - D.P.H.
Effect of 0.031 Sq. In. Second Bead
Effect of 0.087 Sq. In. Second Bead
Weld Metal Area of Primary Bead — Sq. In.

Fig. 4 The effect of second beads on the maximum hardness in the heat-affected zone of sigma bead welds in the nickel-chromium-molybdenum steel

Unionmelt welds, are included to provide a ready means of comparison. It is apparent that all the curves are similar in shape, and it is also apparent that the curves for the groove welds are somewhat displaced from the curve for the bead welds. This was expected, since the cooling rate will logically be somewhat higher in a groove weld, where the molten metal is more nearly surrounded by solid, heat-conducting base metal thus resulting in greater values of hardness in the heat affected zone.

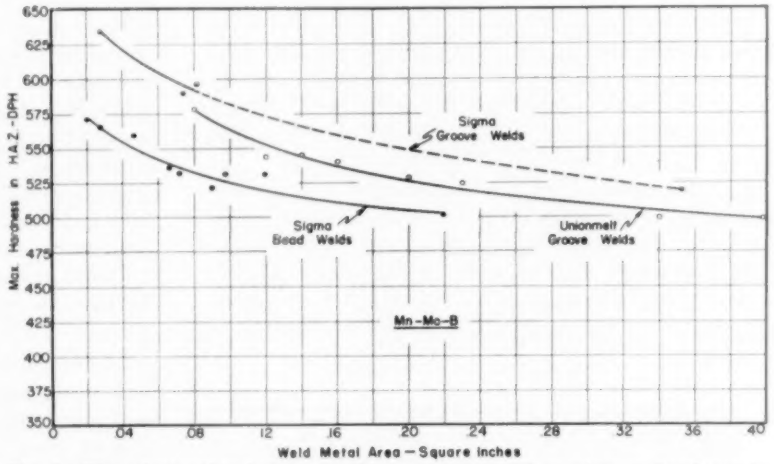

Fig. 5 The relationship between weld metal area and maximum hardness in the heat-affected zone of sigma bead welds and Unionmelt and sigma groove welds in boron-treated manganese-molybdenum steel

EFFECT OF WELD METAL AREA ON IMPACT STRENGTH

Since a significant relationship was established between weld metal area and maximum hardness of the heat-affected zone in the boron-treated manganese-molybdenum steel with both welding processes, further tests were made to determine whether a similar relationship could be detected between weld metal area and notch toughness. The Unionmelt groove welds are used for this study because they closely simulated thermal conditions in actual butt welds, and also because they represented a wider range of weld metal areas than the sigma bead welds. The Charpy vee-notch impact specimen was chosen as the criterion for notch toughness, and the specimens were machined from sections taken from the same welds which were used for the hardness studies.

It is well known that a variety of microstructures is present in the heat-affected zone because the temperature gradient extends from the melting point to the lower critical temperature. Therefore, in order to obtain comparative results, it was necessary to locate the notch at the same relative point in each weld. The notch was located so that the bottom of the vee coincided with the fusion line at the root of the weld. This point was selected because (1) it could easily be located by etching the weld cross sections, (2) the fracture would originate in the hard, coarse-grained area next

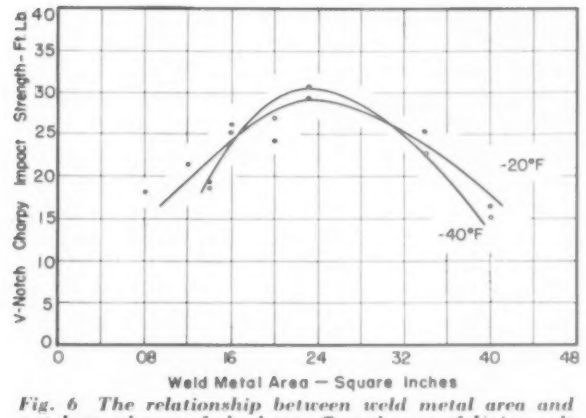

Fig. 6 The relationship between weld metal area and notch toughness of the heat-affected zone of Unionmelt groove welds in boron-treated manganese-molybdenum steel

to the weld which would probably be the most notch-sensitive area in the heat-affected zone and (3) the fracture would propagate through the remainder of the heat-affected zone. The bottom of the vee was parallel to the direction of welding.

The results of the impact tests, which were made at both −20 and −40° F, are shown in Fig. 6. As the weld metal area increased, the impact strength increased to a maximum of about 30 ft-lb at 0.23 sq in. and then decreased with still larger welds. The maximum impact strength occurred at the same weld metal area with both testing temperatures.

Since the maximum hardness of the heat-affected zone was found to be inversely proportional to the weld metal area, the relationship between impact strength and maximum hardness was very similar to that between impact strength and weld metal area. As shown in Fig. 7, the impact strength increased as the hardness decreased and then decreased after a maximum was reached at about 525 DPH. This curve includes only the impact results at −20° F, since there was very little difference between the impact values at the two testing temperatures.

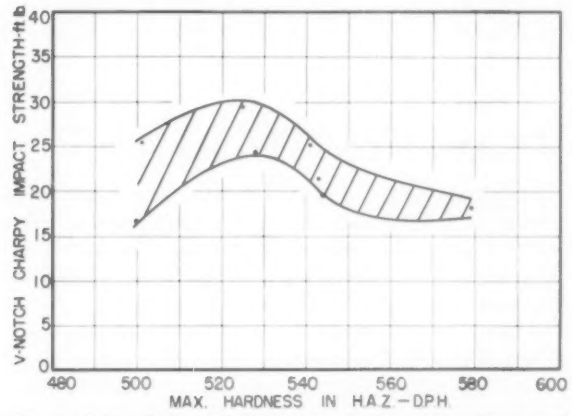

Fig. 7 The relationship between maximum hardness and notch toughness in the heat-affected zone of Unionmelt groove welds in boron-treated manganese-molybdenum plate

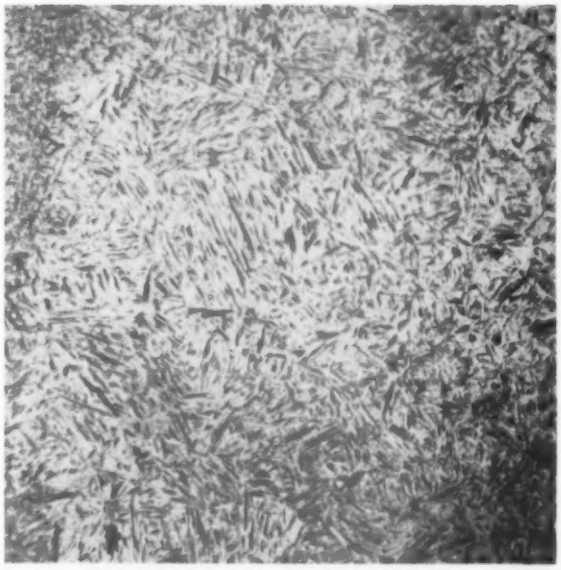

Fig. 8 Heat-affected zone of Unionmelt groove weld having weld metal area of 0.12 sq in. Weld metal visible in upper left. Etched in 5% picral + 2% zephiran chloride. 250 ×

EFFECT OF WELD METAL AREA ON MICROSTRUCTURE

Metallographic examination disclosed that changes occurred in the microstructure of the heat-affected zone next to the weld as the weld metal area changed. These structural changes were gradual, but large differences could be seen between welds of appreciable size variation. Figure 8 shows the microstructure of the heat-affected zone adjacent to a Unionmelt groove weld with a weld metal area of 0.12 sq in., and Fig. 9 shows the structure in a similar location adjacent

Fig. 9 Heat-affected zone of Unionmelt groove weld having weld metal area of 0.34 sq in. Weld metal visible in upper left. Etched in 5% picral + 2% zephiran chloride. 250 ×

to a weld with an area of 0.34 sq in. In Fig. 8, the structure is substantially 100% martensite, while in Fig. 9, a large percentage of the structure is composed of products transformed at a higher temperature. The hardness values of these structures were 543 and 501 DPH, respectively. The structure of the heat-affected zone adjacent to a groove weld having a weld metal area of 0.23 sq in. is shown in Fig. 10. This structure is also predominantly martensite, but a small percentage of other transformation products can be detected. This structure had a hardness of 525 DPH, and also was the most notch tough, according to the results of the impact tests.

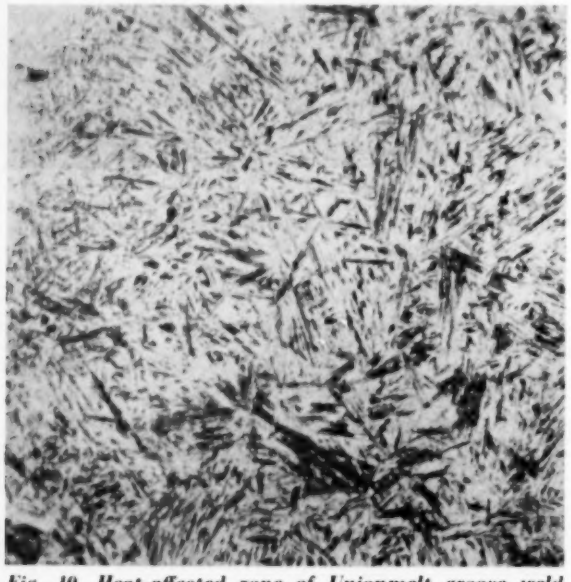

Fig. 10 Heat-affected zone of Unionmelt groove weld having weld metal area of 0.23 sq in. Weld metal visible in upper left. Etched in 5% picral + 2% zephiran chloride. 250 ×

From a study of the microstructures, it appeared that the most notch-tough structure was predominantly martensite with a small percentage of other transformation products. This would logically be obtained when the cooling rate was such that the continuous cooling curve would barely intersect the "nose" of the transformation diagram. A faster cooling rate resulted in a martensitic structure which transformed at a lower temperature and was harder and more brittle. A slower cooling rate resulted in a more mixed structure which apparently was more notch sensitive, although the hardness was relatively lower.

At the outer extremity of the heat-affected zone, little, if any, difference could be detected among the various welds.

DISCUSSION OF RESULTS

Tests were made which showed that a significant variation occurred in the maximum hardness of the heat-affected zone as the weld metal area changed. This variation in maximum hardness was associated with a change in microstructure. Since notch toughness is related to microstructure, tests were made to determine whether significant differences in impact strength could be obtained among these welds. The results showed that the maximum impact strength in the heat-affected zone of the manganese-molybdenum steel was associated with a weld metal area of 0.23 sq. in., and was significantly higher than values obtained with larger or smaller welds.

These data indicated that a weld metal area of about 0.23 sq in. should be used to obtain the best impact properties in the heat-affected zone of a single-pass weld in this steel. However, relatively few welds are completed in a single pass, and it was necessary to consider multipass welds as well. Normally, a tempered structure will have better impact properties than a similar structure which has not been tempered, and it is known that a weld bead and its heat-affected zone can be tempered by the deposition of a second bead. However, it was necessary to determine whether the size of the second bead relative to the first bead was important. Data from a series of two-pass welds in two different steels showed that this size relationship was important, and that the heat-affected zone of a given sized weld was appreciably softened by the deposition of a second bead of approximately the same size. This was true for weld metal areas of approximately 0.03 and 0.09 sq in., and it is believed that the results can be extrapolated to larger weld metal areas, at least within reasonable limits. In these tests, the hardness measurements were made in the heat-affected zone at the root of the first bead. This was the section of the heat-affected zone most remote from the second bead and, therefore, it was tempered to a lesser degree than other sections nearer the second weld bead. Thus, by using equal sized beads, it should be insured that the entire original heat-affected zone would be tempered to a lower hardness.

In welding this particular steel, the results of laboratory tests indicated that the best impact properties in the heat-affected zone would be obtained by using a weld metal area of approximately 0.23 sq in. and by using as many passes of this size as required to complete the weld.

TESTS OF LARGE WELDED PLATES

It was considered desirable to supplement the laboratory tests with tests of large welded plates, so two 36-in. square weldments were prepared in the 1-in. thick manganese-molybdenum steel. Each weldment was made from three 12- x 36-in. sections and contained two 36-in. long butt welds. Unionmelt welding was used, and the edge preparation was similar to that used for the laboratory groove welds, except that a double bevel was used and full welds were made.

Each weld in the first plate was composed of four passes. The root passes from each side were relatively

small, and the second passes were large enough to wash out the root passes, so that the majority of each weld was actually composed of two passes, each pass having a weld metal area of approximately 0.40 sq in. Each weld in the second plate was composed of four equal sized passes, with each pass having a weld metal area of approximately 0.23 sq in. Both plates were submitted to a shock test which applied a dynamic impact load of approximately 140,000 ft-lb.

The first plate, containing the 0.40 sq in. weld nuggets, broke into two pieces when subjected to the first impact, the failure occurring in the heat-affected zone immediately adjacent to one of the welds. The second plate, containing the welds made with four passes of approximately equal size, successfully withstood six consecutive impacts without cracking in the heat-affected zone. These results substantiated the laboratory tests which indicated that the heat-affected zone of a weld made with equal sized passes having an area of 0.23 sq in. each should be more notch tough than the heat-affected zone of a weld made with final passes having an area of 0.40 sq in. each.

The technique of using equal sized beads was further substantiated by a similar test of another weldment made from a different steel. Each weld in this plate was composed of four passes, each pass having a weld metal area of approximately 0.23 sq in. This plate was subjected to the shock test four times, and no cracking was detected.

SUMMARY

Since weld metal area is a primary variable which can be controlled by the operator in welding a given steel, it seems important that any effect of this variable on the properties of the weld zone should be known. The results of this investigation appeared to substantiate the concept that the properties of the heat-affected zone are related to the size of the weld bead. This relationship was expressed quantitatively in terms of hardness and notch toughness, and the results of the laboratory tests were supported by tests of large welded plates.

With respect to multipass welding, it was found that the heat-affected zone at the root of a weld bead of a given size was appreciably softened by the deposition of a second bead of similar size. This was not true if the second bead was either very large or very small with respect to the first bead.

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The Corneille Bridge in Rouen

by J. Velitchkovitch and A. Schmid

THE entirely welded steel Corneille bridge, Fig. 1, is designed to carry heavy highway traffic over two branches of the Seine River each 325 ft wide. The two halves of the bridge are identical, Fig. 2, the central independent girder being supported on the two cantilevers. A design of a similar bridge in reinforced concrete was rejected on account of expense and aesthetics. The concrete bridge would have required 45,000 cu yd of masonry and 8000 tons of reinforcing bars, compared with 16,500 cu yd of masonry, 14,000 tons of bars and 4800 tons of plates for the welded design. A design in prestressed concrete was rejected as too expensive, while a two- or three-hinged arch would have involved too steep a roadway and would have been too difficult to construct.

Desirable from the aesthetic standpoint of thinness at the middle, the welded design also was inexpensive. The Gambetta riveted bridge of recent construction at Soissons cost 103 franks per kilogram, whereas the Corneille bridge cost 90 francs per kilogram.

J. Velitchkovitch is Bridge Engineer of the Port of Rouen, France.

Abstract of "Le Pont Corneille à Rouen," a paper presented before the French Society of Welding Engineers, Dec. 11, 1951, and published in *Soudure et Techniques Connexes*, **6**, 103–122 (1952). (Abstracted by Dr. G. E. Claussen.)

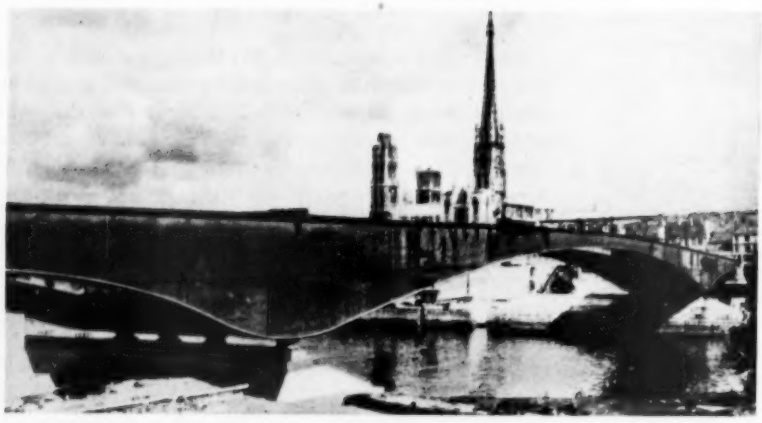

Fig. 1 A view of one span of the Corneille Bridge

The bridge consists of nine box girders side by side. Only four had been erected at the time Fig. 1 was made. The seven interior girders are spaced 9.8 ft apart, with the outside girders at 13.6-ft spacing. The dimensions of the cantilevers and independent girders are given in Figs. 3 and 4. Details of the box girders and of the braces between girders are shown in Figs. 5 and 6. The girders were fabricated in the shop. Only the bracing was site welded.

Open-hearth steel Ac 42 (min tensile strength = 60,000 psi) was used exclusively and was furnished by three steel companies. The tests imposed on the steel were: analysis, bead-bend test, notch-bend test and macrostructure. Radiography was used for inspection. The first two cantilever girders to be completed were placed back to back and subjected with hydraulic jacks to a test load. The test corresponded with a live load of 162 tons (equal to 178 short tons) in the most unfavorable position, namely no load on the shore section but all the load on the river section. The test was satisfactory. A survey with 85 strain gages revealed no inelastic action.

The independent girders were made by Etablissements Schmid Bruneton et Morin at Gennevilliers. Each web consists of four plates butt welded together. Three layers were deposited on each side, the plates being turned over after each layer. The butt welded webs then were flame cut to the required curvature. The flange plates were butt welded together first, then the cover plates were welded to them. To assemble the webs and flanges, the lower flange was jigged to shape. The two webs were set in position separated by the internal framework, Fig. 5, which had been welded in advance. The upper flanges were fitted to the webs. The framework and stiffeners were welded to the webs following which the important welds joining flanges to webs were made. Eight welding operators made all the web-flange joints simultaneously, starting from the middle of the girder. Finally the ends of the internal framework were welded to the upper and lower flanges.

The cantilever girders were fabricated by Ateliers des Enterprises Metropolitaines et Coloniales in Rouen.

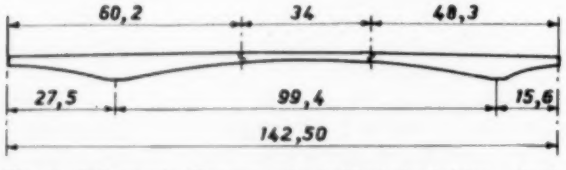

Fig. 2 Schematic diagram of a half of the bridge. Both halves are identical. Dimensions in meters (142.50 meters = 465 ft).

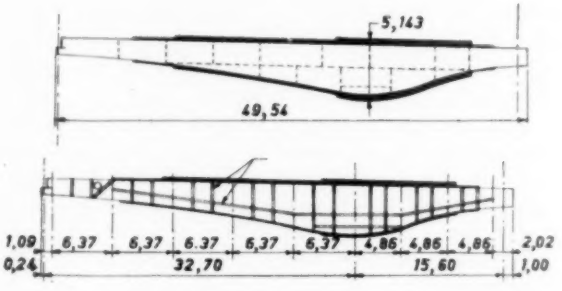

Fig. 3 Dimensions of the cantilevers in meters
(*Upper*) Outside of the external cantilevers. For good appearance stiffeners were omitted from the outer surface of the external cantilevers. Dotted lines show the 15 plates of which each web is composed. (*Lower*) Internal cantilevers showing stiffeners and reinforced manhole. The web is 0.79 in. thick, 17 ft. high over the central supports.

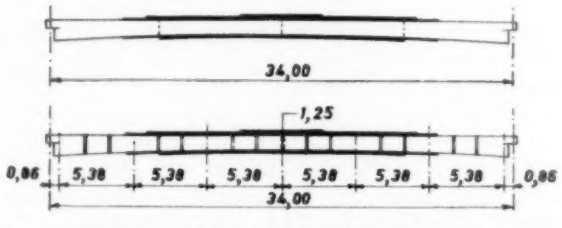

Fig 4 Dimensions of the independent girders in meters
**(*Upper*) Outside girders. Dotted lines show the four plates 0.47 in. thick of which each web is composed.
(*Lower*) Internal girders showing stiffeners.**

The web plates are 0.63 and 0.79 in. thick. Over the central support the 0.79-in. web plates were reinforced by a plate of the same thickness 6 ft square. The reactions at these supports are 360 tons on the mainland, 290 tons on the island. To avoid accumulation of welds, there were no vertical butt joints in the web plates near the supports. Only vertical joints reached the lower flange. The horizontal joints terminated at vertical joints.

Split I beams served as stiffeners with 0.16-in. fillets interrupted at the web plate butts. Stiffeners were omitted from the outer surface of the end girders. Full I sections were used as stiffeners on the interior side of these webs. Discontinuous fillets, 0.20- to 0.43-in. throat

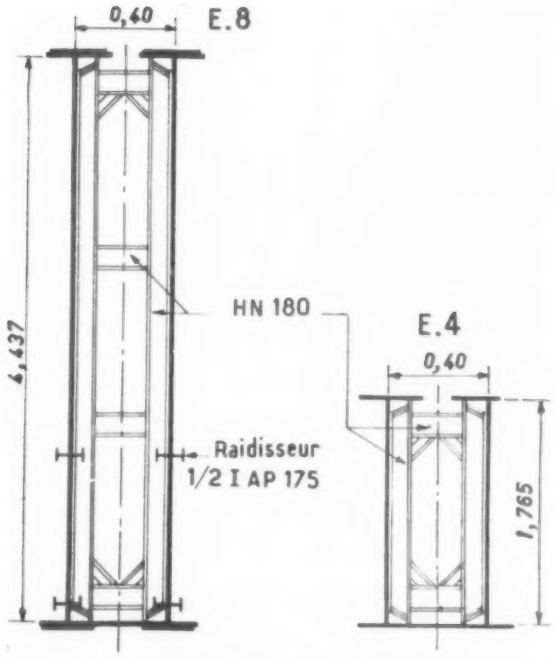

Fig. 5 Two sections through a cantilever box girder. Dimensions in meters (4.437 meters = 14½ ft).

were used to join the webs to the lower flanges. To prevent corrosion the unwelded sections were closed with a light fillet ⅛-in. throat. The lower flange is common to both webs and is 49 in. wide, the thickness varying from 0.59 to 1.0 in. It is reinforced by cover plates 16 x 1, 16 x 0.79 and 12 x 0.79 in. The maximum flange thickness over the central supports is 2¾ in. The butts in the webs and flanges never were placed in the same transverse section. At the junction of flange plates of unequal thickness, the thicker is tapered to the thickness of the thinner over a length of 2¾ in. The ends of cover plates were cut trapezoidal.

The upper flange is in two parts, Fig. 5, to facilitate welding and painting. Each flange is 20 in. wide, 0.71 to 1.0 in. thick, the maximum thickness being 2¾ in. The cover plates are narrower, 16 and 18 in., to permit easy deposition of the fillet welds. The fillets are 0.20-in. throat, 50% discontinuous, with a small seal weld in the gaps to prevent corrosion.

The cantilevers were fabricated in several sections. Each web plate with its upper flange, stiffeners and internal framework was made in two or three sections, lengths being limited by the set-up table. For each of these elements the flame-cut plates constituting the web were tacked and butt welded. First two manual passes were made in the transverse joints followed by a

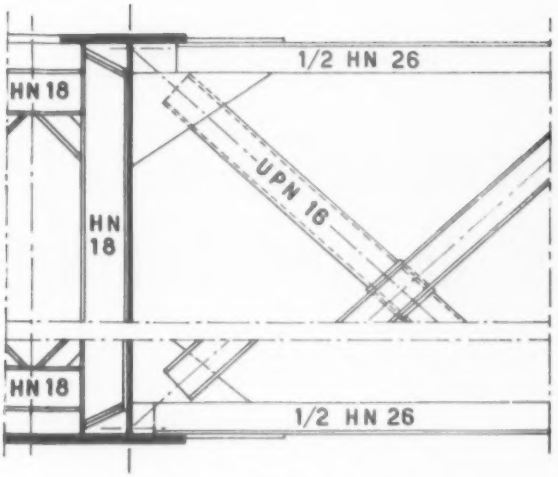

Fig. 6 Bracing between girders

single manual pass in the longitudinal joints. The upper flange then was tacked to the web. The element was turned over and the roots of the welds were chipped. Two passes were deposited in each transverse butt followed by two passes in the longitudinal butts. Submerged arc welding was used to finish the welds, starting again with the transverse butts.

The element then was turned over a second time. Submerged arc welding was used to finish the butts and the web flange fillet. The stiffeners also were welded. For a third time the element was turned over. The stiffeners and the interior framework were attached. The order of assembling the elements was:

1. The lower flanges were jigged to the required curvature.
2. The first element of the first web with its upper flange, stiffeners and internal framework was set in place and welded to the lower flange.
3. The other elements of the first web were set in place.
4. The elements were butt welded together simultaneously at the web and the upper flange.
5. These elements were welded to the lower flange.
6. The second web with its upper flange and stiffeners was set in place.
7. This is welded to the interior framework, then to the lower flange.

Two slight difficulties were encountered in fabricating the girders. There was a tendency for poor root fusion, which was remedied by extensive chipping. Also the web plates tended to distort when the reinforcing plates were applied over the supports. The difficulty was overcome with preheat.

Decomposition of Austenite in Low Carbon, Ni, Mo, Steel Weld Metal

Isothermal decomposition studies of a low carbon, nickel, molybdenum and vanadium steel deposited as weld metal including cooling diagrams and microstructures

by E. F. Bailey and W. J. Harris, Jr.

Abstract

Isothermal decomposition studies were made on small sections cut from a weld pad of the following composition: 0.08% C, 0.45% Si, 1.05% Mn, 2.00% Ni, 0.75% Mo, 0.25% N, 0.25% Cr. The TTT diagram had three reaction ranges—upper and intermediate types of nucleation and growth reactions with no eutectoid microstructure, and a martensite reaction at lower temperatures. The influence of decomposition during cooling to an isotherm on isothermal decomposition is discussed. A continuous-cooling diagram obtained by dilatometry indicated initiation of the transformations along horizontal temperature shelves except in the regions of partial suppression. A completely martensitic structure was obtained only at water-quenching rates.

INTRODUCTION

THE decomposition of austenite in weld metal even though of tremendous practical importance has not been given much attention in terms of controlled studies on as-deposited weld metal. Only one previous investigation has been reported for as-deposited weld metal.[1]

This present work was initiated because of the increased use of the weld metal studied and the value that the knowledge of its decomposition characteristics, both isothermal and continuous cooling, would have for its users. In addition, the effects of continuous cooling on isothermal decomposition is demonstrated.

EXPERIMENTAL PROCEDURE

Material

A weld pad, 12 x 4 x 1 in., from which all the specimens were cut was supplied by Philadelphia Naval Shipyard, Industrial Test Section. The chemical composition was determined by analysis of chips taken from the volumes indicated in Fig. 1. Chemical analyses of the various samples are given in Table 1. In general, the composition was fairly constant with slight changes in the C, Si and Mn content from edge to center. The pattern of passes in the longitudinal and transverse sections is shown in Fig. 2. This figure also indicates microsegregation at the interface of the passes.

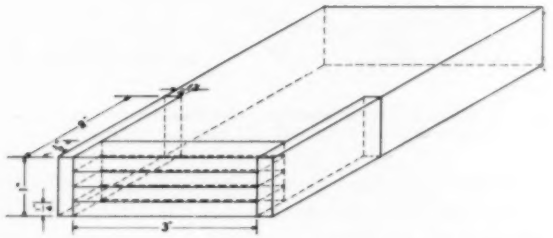

Fig. 1 Locations of volumes for chemical analysis chips

Heat Treatment

Specimens used for metallographic determination of the transformation characteristics were $^{7}/_{16}$ x $^{3}/_{16}$ x $^{1}/_{16}$ in. The time-temperature cycles for heating to the austenitizing temperature and for quenching were meas-

Table 1—Chemical Analyses of Weld Samples

	Origin of Sample					
Element	*Top, $^{1}/_{4}$ in.*	*Top center, $^{1}/_{4}$ in.*	*Bottom, $^{1}/_{4}$ in.*	*Bottom center, $^{1}/_{4}$ in.*	*Left side*	*Right side*
C	0.086	0.080	0.084	0.086	0.092	0.092
Si	0.44	0.44	0.44	0.45	0.53	0.51
Mn	1.04	1.03	1.02	1.02	1.10	1.09
Ni	2.00	2.00	2.00	2.00	2.00	2.06
Mo	0.73	0.75	0.77	0.76	0.75	0.74
Cr	0.17	0.17	0.18	0.18	0.19	0.15
V	0.25	0.25	0.24	0.25	0.25	0.25
P	0.013	0.014	0.014	0.014	0.014	0.014
S	0.015	0.015	0.015	0.015	0.015	0.015

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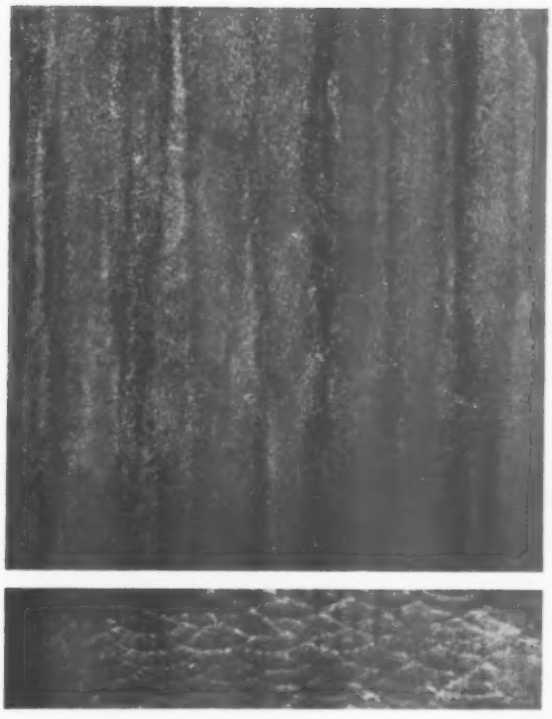


Fig. 2 Macrophotograph of longitudinal and transverse areas of the weld pad

ured by using the specimen as the hot junction in a Chromel-Alumel circuit in conjunction with a high-speed recording potentiometer. The size of the Chromel-Alumel wire was No. 28 gage. A vertical tube furnace with inert atmosphere was used for austenitizing. All specimens were austenitized at 2000° F for 20 min. No primary carbides were evident in specimens quenched to room temperature after this austenitizing treatment. Lead baths were used for the isothermal studies. Prior to metallographic polishing 0.015 in. was ground off each specimen to eliminate any possible decarburization effects. The etchant used was 4% nital.

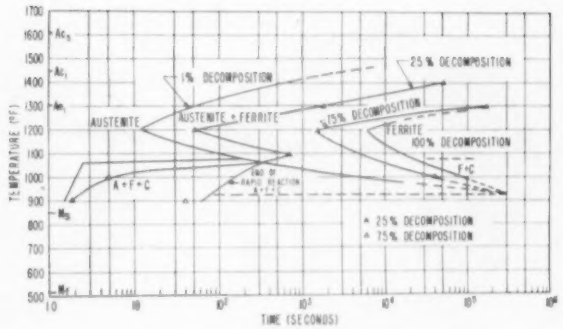


Fig. 4 Isothermal transformation diagram obtained by considering the decomposition temperature to be the same as the temperature of the isothermal bath

Dilatometry

Three types of dilatometers were used: A clear fused quartz quenching dilatometer to supplement the metallographic investigation of the specimens used in the isothermal studies, and two types of continuous cooling dilatometers; one for cooling rates up to 180° F/min; the other, a high-speed dilatometer[2] for quenching rates similar to those observed in oil and water quenching.

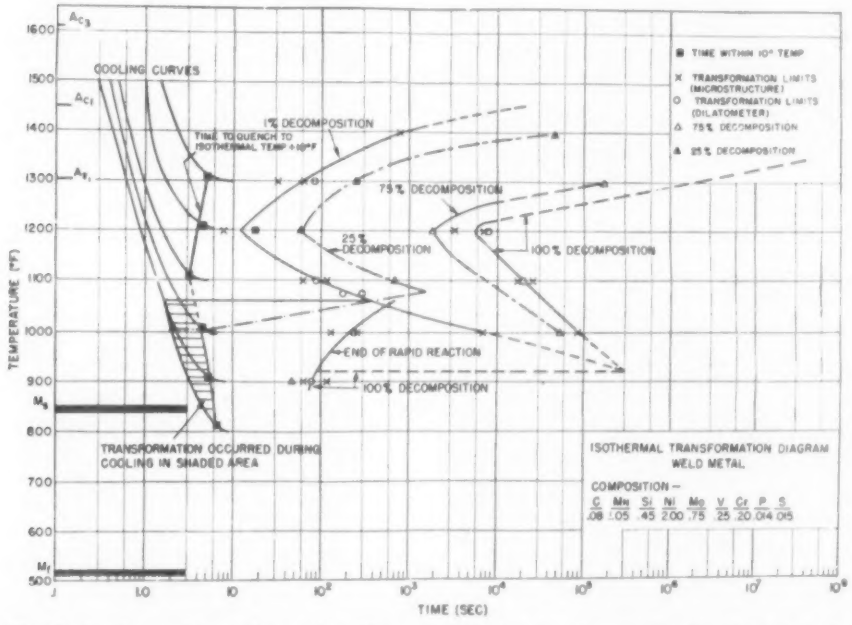


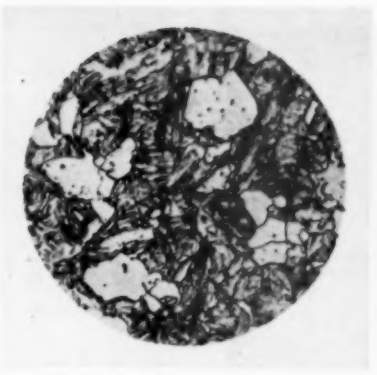
Fig. 3 Isothermal transformation diagram utilizing continuous cooling data for the metallographic specimen

RESULTS

Transformation Observed During Cooling to Isothermal Bath

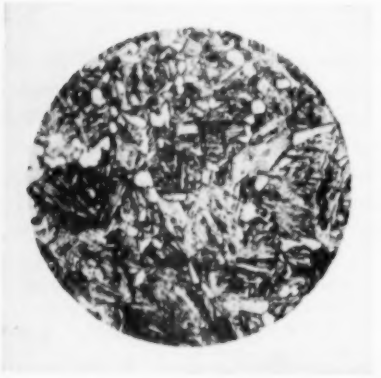
In most isothermal studies the decomposition is assumed to take place at the isothermal bath temperature. This method may not give a true picture of isothermal reactions since some decomposition may take place during cooling. Figures 3 and 4 are the transformation curves which are derived from the above-mentioned approaches using the data collected in this isothermal study. The difference is readily apparent; Fig. 4 is plotting of data considering isotherms only; Fig. 3, is

Temp., 1400° F; time, 15 min



Temp., 1300° F; time, 8.5 min

Temp., 1200° F; time, 64 sec



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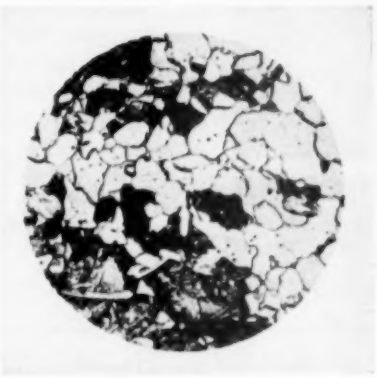

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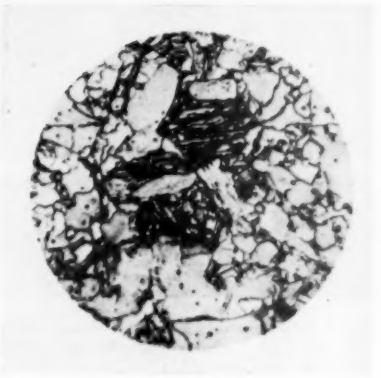

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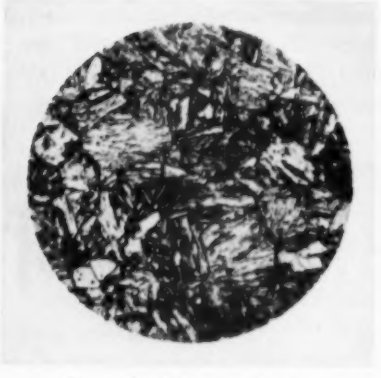
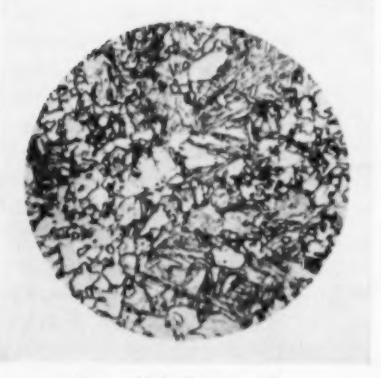


Temp., 1100° F; time, 15 min

Temp., 1000° F; time, 8 sec

Temp., 900° F; time, 8 sec



Temp., 1100° F; time, 2 hr

Temp., 1000° F; time, 10 hr

Temp., 900° F; time, 32 sec

Fig. 5 Microstructure resulting from isothermal decomposition for given temperatures and times. × *400*

plotted using continuous cooling data for the metallographic specimens in conjunction with the microstructure. The cooling curves of the specimens to each isotherm are incorporated in Fig. 3. A locus of points for the time necessary to quench within 10° F of the isotherm being studied is shown and reveals very pertinent information. This locus of points has a change in slope between 1000 and 1100° F indicating recalescence due to decomposition which began to take place during continuous cooling in this temperature region. A close study of the cooling curves and microstructure of metallographic specimens which had been quenched below this region verified that decomposition started during cooling at 1060° F in all the specimens. The shaded region in Fig. 3 indicates the region in which decomposition is taking place during cooling.

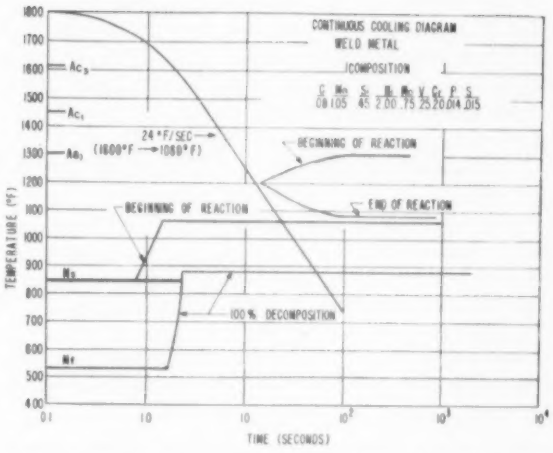


Fig. 6 Continuous cooling transformation diagram

Transformation Characteristics

The Ac_1 and Ac_3 for this steel were determined dilatometrically during continuous heating and were repeated within 5° F in 20 tests. The results were insensitive to heating rates within this tolerance. The Ae_1 was measured dilatometrically by holding isothermally for 7 hr and was found to be 1300° F.

The isothermal suberitical decomposition of austenite is best described by reference to time-temperature regions in Fig. 3. In the upper region (1060 to 1400° F) decomposition went continuously to completion by decomposition to ferrite. No eutectoid microstructure was produced in this region even when 100% decomposition occurred. In the range (925 to 1060° F) decomposition occurred by two isothermal transformations. The first was a rapid reaction (in point of time) which appeared to be a continuation of the decomposition which occurred during continuous cooling; the second, a reaction which commenced after prolonged holding and proceeded until the austenite was completely decomposed. This second reaction is felt to be similar in nature to the decomposition which took place in the upper region, since extrapolation of the beginning and ending curves of the upper transformation to the beginning and ending times for this second reaction gives a smooth curve. In the lowest temperature range of isothermal decomposition (850–925° F) decomposition was completed by the rapid reaction, which was noted as the first reaction between 925 and 1060° F. Representative microstructures developed in this steel are shown in Fig. 5.

The lowest transformation could not be suppressed by brine quenching and is considered to be martensite. M_s for this steel is 850° F; M_f is 515° F.

Characteristics of Continuous Cooling Transformation

The continuous cooling diagram is presented in Fig. 6. This diagram was determined dilatometrically. For slow quenching rates it was found that the time for the beginning of transformation fell along a nearly constant temperature level of 1300° F. At quenching rates of 10° F per second partial suppression of the upper transformation began; complete suppression was realized at approximately 20° F per second. There appeared to be even at the slowest rates a separation between the upper and intermediate reactions during continuous cooling. The intermediate reaction began at the 1060° F isotherm until quenching rates were fast enough to cause suppression of the reaction Oil quenching caused partial suppression while quenching in still water completely suppressed the intermediate reaction. The partial decomposition to the intermediate product during oil quenching did not appear to affect M_s.

The cooling curve presented in Fig. 6 (24° F/sec) shows the cooling behavior of a weld metal deposited on a 0.5-in. plate as reported in a previous investigation.[1] It can be seen from this that the weld rod studied here will yield the microconstituent concomitant with the intermediate reaction under this practical condition.

DISCUSSION

Figures 3, 4 and 6 are in agreement as to time-temperature region of the upper transformation.

In general the transformation diagram is similar to those previously observed for Mn-Mo wrought steels.[3]

In the intermediate range (850–1060° F), however, the transformation during cooling to the isotherm as shown in Fig. 3 must be taken into account. Comparison of Figs. 3 and 4 demonstrate how the recognition of decomposition during cooling can change the appearance of the isothermal diagram. In Fig. 4 the downward curvature of the lines drawn as the beginning of the intermediate reaction is incorrect because decomposition is apparent during cooling to the isotherms 1050, 1000 and 900° F. Decomposition begins at 1060° F independently of the isotherm eventually reached. For example, Fig. 3 correctly shows in quenching to 1000° F that 25% decomposition occurs between 1060 and 1000° F while Fig. 4 depicts it as a rapid transformation at 1000° F.

A comparison of Figs. 4 and 6 also demonstrates another discrepancy which can arise by not considering the decomposition during cooling. A possible complete suppression of any reaction by quenching to 900° F for 1.5 sec is shown in Fig. 4, but is not corroborated by Fig. 6 which is the continuous cooling diagram.

A comparison of the isothermal and continuous cooling transformations in this steel indicates the importance of continuous cooling in fostering the intermediate transformation. In the isothermal study a rapid reaction which starts during continuous cooling ceases in a very short interval after coming to temperature without complete decomposition of the austenite; whereas, in the continuous cooling study transformation continues with lowering of the temperature in the time-temperature region in which no apparent transformation occurs isothermally. This suggests that this decomposition during continuous cooling is dependent on continuing formation of nuclei rather than growth of existing nuclei or that a mode of decomposition similar to martensite is the mechanism for the transformation.

These results may be the basis for a more general discussion of the respective importance of isothermal and continuous cooling data. Isothermal diagrams have played an important role in demonstrating the types of transformations that occur in steels. Since most commercial heat-treatment operations, however, involve continuous cooling, very elaborate studies have been made to obtain empirical equations which allow the preparation of continuous cooling diagrams from isothermal data. This investigation has shown for this low-alloy steel that significant amounts of transformations occur during cooling to the isotherm. It would appear from this that isothermal studies of low-alloy steels should be examined most carefully to be sure that they do not include some continuous cooling data. Furthermore, it appears that direct determination of continuous cooling diagrams should be furthered.

SUMMARY AND CONCLUSIONS

1. Pearlite is not formed during decomposition of austenite in this steel.

2. Specimens used for isothermal studies undergo transformation during cooling to isotherms below 1060° F.

3. A transformation diagram which separates the decomposition which occurs during cooling to an isotherm from decomposition at the isotherm is more indicative of the transformation characteristics of a steel than diagrams which represent all decomposition to be a function of the isotherm being studied.

4. Two isothermal transformations occur in the region from 880 to 1060° F. The first transformation is of short duration, and appears to be a continuation of the transformation during cooling; the second begins after a longer time at temperature and appears to be similar in nature to the high temperature transformation.

5. The intermediate transformation occurs continuously during continuous cooling but discontinuously during isothermal holding.

6. Water quenching or faster means of quenching was necessary to form martensite. M_s is 850° F; M_f is 515° F.

ACKNOWLEDGMENT

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Effects of Carbon, Oxygen and Nitrogen on Welds in Titanium

Limits of carbon, oxygen and nitrogen which can be tolerated in titanium spot welds and welds made with inert-gas shielded arc

by D. C. Martin

TITANIUM, and its alloys, show promise of assuming an important place as a material of construction in the aircraft industry. To use any structural material in a satisfactory manner it is necessary to devise practical fabrication methods. One of the fabrication methods which must be understood is the joining of a material both to itself and to other materials. Welding is an important method of fabricating when joining a material to itself and is quite often used for joining one material to another.

Titanium and its alloys can be welded, but the welded joints may not be useful because of low ductility. It has been suggested that low ductility in welded joints is caused by the presence of various elements in the titanium whose basic effect on the weld and heat-affected zone properties are not well understood.

There are many alloying elements which are used with titanium. Some of these are added intentionally, but three which are nearly always present—and perhaps not intentionally—are carbon, oxygen and nitrogen. Hydrogen may also be present in titanium or titanium alloys but this element was not included in the investigation reported here. All of these elements may be picked up by titanium during melting and fabrication, and in addition oxygen and nitrogen may be introduced into a weld during welding. It has been shown by other investigators that carbon, oxygen and nitrogen can affect both the strength and ductility of titanium. If present in sufficient quantities, oxygen and nitrogen, in particular, can reduce the ductility of titanium to nearly zero.

Because these three elements are present in most commercial titanium and because it is difficult to prevent their occurrence, the Air Material Command initiated an investigation at Battelle Memorial Institute to study the effects of carbon, oxygen and nitrogen on the properties of welds and weldments in titanium sheet. The objective of this investigation was to determine what effects carbon, oxygen and nitrogen had on the strengths and ductilities of titanium welds and to determine, if possible, a maximum limit of carbon, oxygen and nitrogen which could be tolerated in titanium weldments. This report summarizes the results of the investigation.

The investigation was carried out by making inert-gas-shielded tungsten-arc welds and spot welds in sheets of various thicknesses. A range of compositions of titanium-carbon, titanium-oxygen and titanium-nitrogen alloys was investigated. The strength and ductility properties of weldments in the alloy sheets were compared with the results of studies of the metallurgical structures of welds and heat-affected zones to determine the cause of variations which were found in the various alloys.

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SUMMARY

Inert-gas-shielded tungsten-arc welding and spot-welding tests were made on unalloyed iodide and unalloyed sponge titanium sheet. The same types of welding test were also made on titanium-carbon, titanium-oxygen and titanium-nitrogen-alloy sheets. These alloys were made using sponge titanium. The titanium-carbon alloys included compositions from 0.13 to 0.74% carbon. The oxygen-alloy series included compositions from 0.15 to 0.55% oxygen. The nitrogen-alloy series included compositions from 0.13 to 0.50% nitrogen. However, the 0.50% nitrogen alloy could not be fabricated into sheet and no welding tests were made on it.

Most of the inert-gas-shielded arc welding was done in a controlled-atmosphere chamber. A few tests were made in the open on the unalloyed sponge sheet using only the gas from the welding torch for shielding and a solid copper bar as a backup. These tests showed that when titanium is welded under these conditions contamination by oxygen and nitrogen may cause high hardness and lowered ductility in the weld. The use of a trailing shield and gas backup would nearly eliminate this contamination. However, for this investigation it was desirable to reduce the variations caused by air contamination to a minimum and consequently most of the tungsten-arc-welding work was done in the controlled-atmosphere chamber.

Table 1—Summary of Results of Tests Made with Unalloyed and Alloyed Titanium Sheet.[1] Alloyed Sheet Made with Sponge Titanium

Material	Unwelded Sheet						Inert Gas-Shielded Arc–Welded Sheet					Spot-Welded Sheet		
	Ultimate Tensile Strength, psi	Yield Strength, psi[2]	Elongation in 2 inches, %	Reduction of Area, %	Minimum Bend Radius[3] Longitudinal	Minimum Bend Radius[3] Transverse	Ultimate Tensile Strength, psi	Elongation in 2 inches, %	Reduction of Area, %	Minimum Bend Radius[3,4] Longitudinal	Minimum Bend Radius[3,4] Transverse	Tension-Shear Load, lb	Cross-Tension Load, lb	Tension-Shear Ratio[5]
Iodide	43,400	24,000	53	67	<1T	<1T	43,100	34	55	1T	<1T	1,875	1,050	0.56
Sponge (welded in chamber)	66,900	45,700	30	44	<1T	1T	70,800	22	37	3T	2T	–	–	–
Sponge (welded in open)	–	–	–	–	–	–	71,100	19	0	4T	4T	2,400	900	0.37
0.13% carbon	76,200	62,800	34	48	1T	1T	81,700	23	39	4T	3T	2,500	1,500	0.60
0.28% carbon	91,300	77,400	24	33	2T	2T	93,800	24	19	8T	>12T	2,600	800	0.31
0.55% carbon	98,700	76,300	21	33	4T	6T	92,300[7]	2	9	12T	>12T	2,400	300	0.13
0.74% carbon	94,200	78,100	8	12	6T	8T	95,500[7]	1	5	>12T	>12T	1,600	300	0.19
0.15% oxygen[6]	93,400	81,600	23	40	3T	2T	96,000	10	24	3T	2T	2,600	1,200	0.46
0.30% oxygen[6]	111,000	95,200	27	38	3T	8T	101,000	12	15	12T	>12T	2,800	900	0.32
0.55% oxygen[6]	126,000	120,500	3	7	>12T	>12T	103,000[7]	0	2	>12T	>12T	1,250	60	0.05
0.13% nitrogen	112,000	98,300	20	39	3T	4T	113,000	13	16	8T	>12T	2,750	400	0.15
0.24% nitrogen	118,000	113,000	28	4	5T	>12T	120,000[7]	0	0	>12T	>12T	2,100	300	0.14
0.50% nitrogen	Could not be rolled to sheet						–	–	–	–	–	–	–	–

(1) Values for 0.064-inch sheet used since they are reasonably representative.

(2) 0.2% offset yield strength.

(3) Minimum punch radius in terms of sheet thickness around which specimen would bend without cracking. 1T is approximately 33% elongation over short gage length which depends on sheet thickness. 12T is approximately 4% elongation.

(4) All bend specimens failed in weld except those made with the titanium–0.28 per cent carbon alloy which failed in heat-affected zone.

(5) Cross-tension load / Tension-shear load.

(6) Estimated oxygen content based on amount added plus estimated oxygen content from sponge and pickup during melting.

(7) Fracture occurred in weld. In all other cases fracture occurred in base metal usually outside of heat affected zone.

The results of welding tests are summarized in Table 1. The properties of welds in iodide sheet and in unalloyed sponge sheet are about the same as the properties of the unwelded base metal. The welds are a little harder and the bend ductilities are not quite so good for the weldments as for the unwelded sheets. Spot welds in both the iodide sheet and the unalloyed sponge sheet have good properties. For equivalent thickness, the tension shear strengths of spot welds in the unalloyed sponge sheet are about the same as can be obtained from spot welds in 90,000 psi ultimate strength stainless steel. Spot welds on both the iodide and sponge sheets have good tension-shear ratios (0.38 to 0.56) as determined by the ratio of the cross-tension strength to the tension-shear strength.

The results of tests on the carbon alloys indicate that up to 0.13% carbon these alloys have good weldability. At some composition level between 0.13 and 0.28%, the carbon begins to have an adverse effect on the ductility of both arc and spot welds. This effect is caused by the precipitation of carbide during the freezing of the weld into a network which is more or less continuous depending on the carbon content. This carbide network is brittle and forms good fracture paths through the structure. At 0.55% carbon, the bend ductility of arc welds is practically zero. Heat treatment will not affect the amount of carbide present in the welds in the high-carbon sheet sufficiently to improve their ductility. The properties of spot welds in the carbon alloys, particularly the cross-tension strengths, also deteriorate at some carbon content between 0.13 and 0.28% and for the same reasons. The carbide network occurs in spot welds in higher carbon sheet as well as in arc welds and causes the welds to behave in a brittle manner.

Oxygen begins to have an adverse effect on the properties of welds in titanium at lower concentrations than carbon. Arc welds in titanium containing more than about 0.15% oxygen have low ductility. This low ductility is the result of small cracks which occur in the welds, and the amount of cracking observed increases with increasing oxygen. This cracking is apparently a result of the inherent brittleness of the higher oxygen alloys and probably is caused by shrinkage stresses. Both the tension-shear and cross-tension strength of spot welds in alloys containing more than 0.30% oxygen are low. The ductilities of spot welds in the high-oxygen alloys are low and again this is apparently a result of the inherently low ductility of titanium containing this much oxygen.

Nitrogen has the most adverse effect upon the weldability of titanium of the three elements studied during this investigation. Arc welds in titanium sheet containing 0.13% nitrogen have very low bend ductility.

As in the oxygen alloys, this low bend ductility is caused by cracks which occur in the welds and the base plate adjacent to the welds. However, these cracks appear at much lower alloying levels than with oxygen. When the nitrogen content reaches 0.24%, the arc-welded specimens have no ductility either in bend tests or in tension tests. The deleterious effect of nitrogen is also apparent in spot-welding tests. As with the oxygen alloys, it is most apparent in the cross-tension tests. Spot welds in alloys containing 0.13% nitrogen have about half the cross-tension strength of spot welds in unalloyed sponge titanium sheet. At 0.5% nitrogen, the cross-tension strength is considerably less. The addition of nitrogen does not affect the shear strength of these spot welds as greatly as it does the cross-tension tests. Consequently, the shear ratios of spot welds in nitrogen sheet are very low. Unfortunately the nitrogen alloys used in the tests reported here do not give a complete story of the effect of nitrogen. It is obvious that the 0.50% nitrogen alloy is too high. What is needed to complete the data are some welding tests on an alloy containing from 0.05 to 0.10% nitrogen. Without this, it is possible to say only that 0.13% nitrogen is too high for good weldability without saying what the maximum nitrogen content should be.

The results of this investigation have shown that nitrogen and oxygen in rather small quantities can have very bad effects on both arc and spot welds in titanium. This emphasizes that shielding of titanium from the air during arc welding is very necessary. Shielding of spot welds while they are being made is not so critical because there is much less chance of contamination of the weld by the air.

During this investigation, it has been found that porosity can be a problem in welding titanium. It is believed that porosity in arc welds is caused by hydrogen which may be present as a hydride in the titanium or may be absorbed by the molten pool during welding.

PREPARATION OF TITANIUM SHEET

The materials used in this investigation were arc melted from iodide titanium and from titanium sponge. Both the unalloyed and the alloyed ingots were melted in an arc furnace using a tungsten electrode. The feed material was added during melting as small particles. The iodide crystal bars used were cut into cubes about $^1/_4$ in. square. The sponge titanium was screened to $-^1/_2$ to $+^1/_8$ in. The titanium sponge was leached in methyl alcohol and heated at 750° F for 2 hr before being used. This treatment was used to remove magnesium chloride and minimize spatter. All melting was done under an atmosphere of 99.93% or better argon. The furnace was purged by evacuating it before filling with argon.

The carbon alloys were made by mixing sponge titanium with the proper amounts of powdered graphite. Mixing was accomplished by tumbling the sponge and the graphite in a rotating mill. The graphite-sponge mixture was double arc melted to produce a homogenous ingot. Ingots from the first melting were rolled into plate, and the plate was then cut into pieces which were used as feed material for the second melting.

The titanium-oxygen alloys were made by mixing a master alloy and titanium sponge. The master alloy was made by outgassing titanium sponge in a vacuum and then holding the outgassed sponge for 4 hr at 1380° F in an atmosphere of pure oxygen. This produced an alloy of 4% oxygen. The master alloy was mixed in proper proportions with titanium sponge and double arc melted to produce homogeneous ingots. Ingots containing nominal weight percentages of 0.10, 0.25 and 0.50% oxygen were made. The oxygen alloys have not been analyzed for oxygen content. The oxygen content of the master alloy was determined by weight gain. The nominal compositions of the oxygen alloy reported were determined by using the calculated composition of the master alloy.

The titanium-nitrogen alloys were also made by arc melting titanium sponge and a master alloy. The titanium-nitrogen master alloy was made by arc melting titanium sponge in an atmosphere of 50% dried nitrogen and 50% high-purity argon. The master alloy was analyzed for nitrogen, and the analytical value was used for determining the amount of master alloy to be added to the arc-melt heats. The titanium-nitrogen alloys were made by double arc melting, and the ingots were analyzed for nitrogen after the second melting.

Table 2 shows the forging and rolling temperature used for fabricating the various unalloyed and alloyed titanium ingots into sheet. With one exception, no difficulty was encountered in forging or rolling the various ingots. The exception was the ingot containing $^1/_2$% nitrogen. This ingot cracked badly during rolling, and no sheet was obtained from this alloy.

Table 2—Forging and Rolling Temperatures Used to Fabricate Titanium Sheets from Ingots

	Temperature, ° F		
Alloy	*Forging*	*Rolling to Slab*	*Rolling Slab to Sheet*
Iodide	1450	1450	1250
Unalloyed sponge (Process A)	1450	1450	1250
Carbon alloys:			
0.13%	1650	1450	1250
0.28%			
0.55%	1650	1650	1250
0.74%	1650	1650	1250
Oxygen alloys:			
0.15%	1650	1450	1250
0.30%	1650	1450	1250
0.55%	1800	1650	1250
Nitrogen alloys:			
0.13%	1650	1450	1250
0.24%	1650	1450	1250
0.50%[1]	1800	1700	1700

[1] Rolled to 0.132-in. thickness. Impractical to roll to thinner sheet because of severe cracking.

The sheets were hot rolled to 0.003 in. over final thickness. Scale was removed by sandblasting, and the sheets were then cold rolled to final thickness. After being cold rolled, the sheets were anealed in a vacuum for 10 hr at 1250° F. After annealing, the sheets were pickled in a solution of 50% sulphuric acid containing 60 g ammonium fluoride per liter of solution. All of the sheets except the 0.50% nitrogen had smooth surfaces and were in excellent condition for welding tests. Radiographs showed that all sheets contained a few tungsten inclusions. The positions of these inclusions were determined from the radiographs, and the inclusions were either cut out of the sheet or test specimens were taken so that they did not include the inclusions.

The filler metals used in all of the tests were sheared from the finished sheet.

The compositions and hardnesses of the various sheets produced are shown in Table 3.

Table 3—Compositions and Hardnesses of Titanium Sheet

Alloy, nominal composition	*Actual composition, weight %*	*Average hardness, Vickers*
Iodide	(1)	101
Sponge	(2)	161
Carbon alloys:		
0.10%	0.13	177
0.25%	0.28	253
0.50%	0.55	243
0.75%	0.74	238
Oxygen alloys:		
0.10%	0.15(3)	233
0.25%	0.30(3)	264
0.50%	0.55(3)	323
Nitrogen alloys:		
0.10%	0.13	239
0.25%	0.24	278

(1) Carbon 0.03%, nitrogen 0.004%.
(2) Carbon 0.03–0.09%, nitrogen 0.005–0.01%, oxygen estimated at 0.05% from strength of unalloyed sheet and amount of nitrogen present.
(3) These figures were arrived at by adding the estimated amount of oxygen in the unalloyed sponge sheet to the amount of oxygen added during melting through the oxygen master alloy.

WELDING PROCEDURES

Two types of welding were used in this investigation. Arc-welding tests were made on sheets 0.064 and 0.125 in. thick. Spot-welding tests were made on sheets 0.032 and 0.064 in. thick.

Arc Welding

The inert-gas-shielded tungsten-arc-welding process was used for all of the arc-welding tests made during this investigation. A standard tungsten-arc torch was used. In all tests, the electrode used was $^1/_{16}$ in. in diameter, and high-purity (99.94%) argon was used for shielding. All welding was done using straight-polarity direct current. Arc welding on 0.064-in. sheet was done with an arc voltage of 12 to 14 v and a welding current of 55 to 65 amp. On 0.125-in. sheet, the arc voltage was 15 to 17 v, and the welding current was 100 to 110 amp. The welds produced by these currents were rather wide but full penetration was obtained in nearly all of the welds. The welding speeds used varied for the different sheet thicknesses and were sometimes varied between different lots of sheet to try to eliminate porosity. The details of the specimens used in the arc-welding tests are shown in Fig. 1.

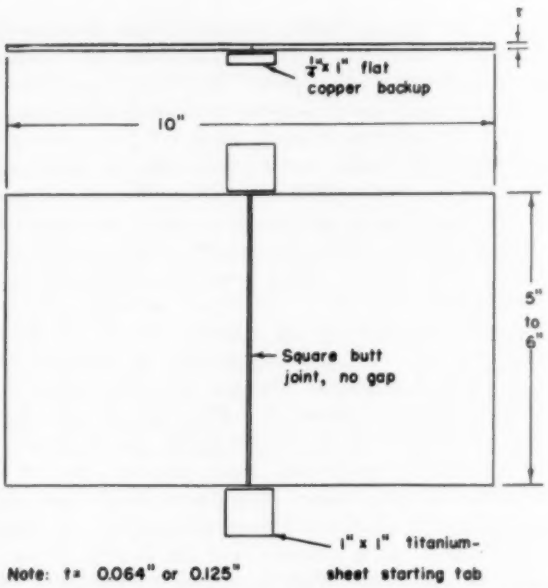


Fig. 1 Details of specimen used for arc-welding tests

Some arc-welding tests were made using only the gas from the torch as a shield. Others were made in the controlled atmosphere chamber shown in Fig. 2. This chamber is purged by evacuating it to low pressures and then admitting the shielding gas desired until a small positive pressure is reached.

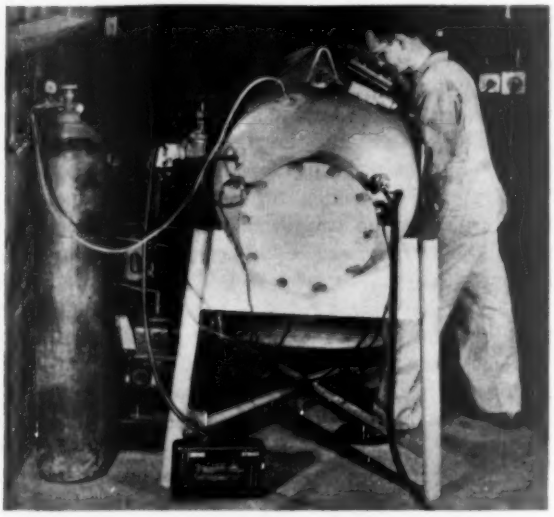


Fig. 2 Controlled-atmosphere chamber used in arc-welding tests

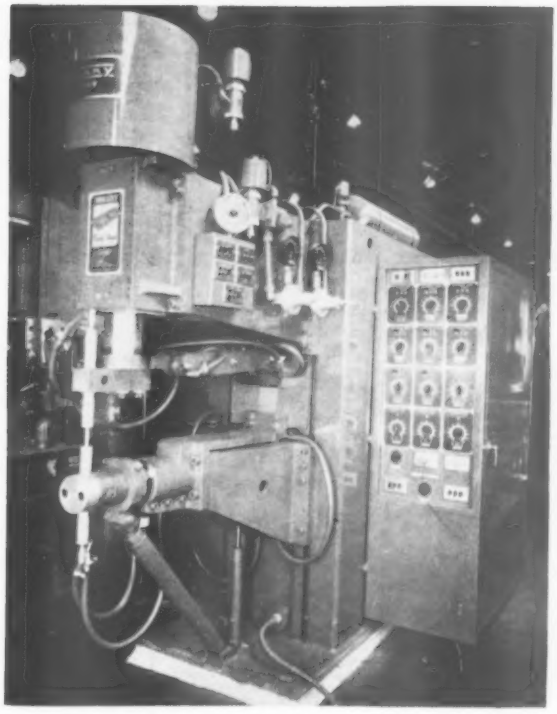


Fig. 3 200-kva, 60-cycle, frequency-converter spot welder used in spot-welding tests

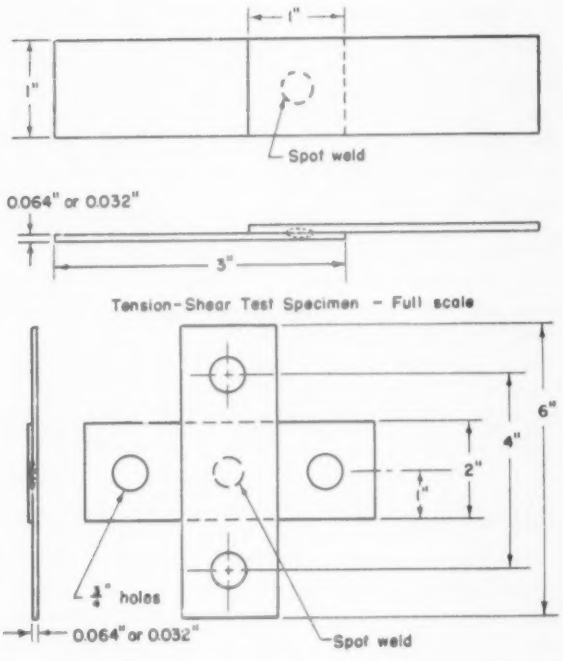


Fig. 4 Details of tension-shear and cross-tension test specimens

Spot Welding

A 200-kva, 60-cycle, 3-phase, alternating-current, frequency-converter-type spot welder was used for all of the spot-welding tests. Figure 3 is a photograph of this spot welder. The electrodes used for welding were made from materials corresponding to RWMA Class 1. The electrodes were $^5/_8$ in. in diameter and were water cooled. The tips of the electrodes had a 3-in. spherical radius face.

The types of spot-welding specimens used are shown in Fig. 4.

The spot-welding conditions used in all spot-welding tests are shown in the following tabulation:

	0.032-In. sheet	*0.064-in. sheet*
Tip force, lb	600	1200
Approximate welding current, amp*	21,000–24,000	25,000–27,000
Number of impulses	1	2
Duration of impulse, cycles	5	5
Off time, cycles	...	1

* Estimated from phase shift-current relationship for machine.

A large number of tests showed that these conditions consistently produced high weld strengths in the titanium sheet. The higher amperages were used with the alloy sheets containing the larger amount of alloying elements. In all tests, the conditions were adjusted to produce spots which had diameters of 3 to 5 times the thickness of the sheet.

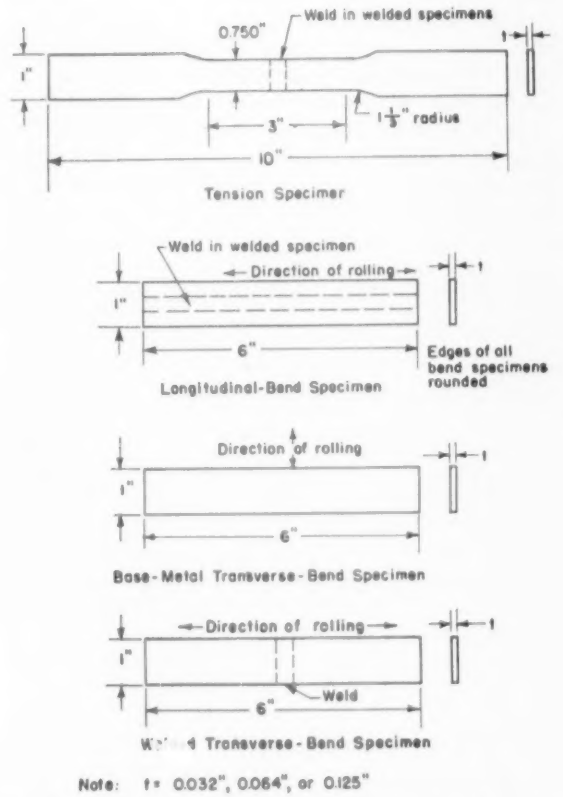


Fig. 5 Details of tension, longitudinal-bend and transverse-bend specimens

PREPARATION OF TEST SPECIMENS

The tests made on the unwelded and arc-welded sheets included tension tests, longitudinal bend and transverse bends tests. Figure 5 shows the details of the specimens used for these tests. The tension specimens were machined to conform with Military Specification MIL-T-5021.

Strain gages (SR-4 Type A-1) were used on the tension specimens cut from unwelded sheet to determine the yield strength of the sheet. The specimens were also scribed with 2-in. gage lengths which were used to determine elongations.

The 1-in. width was selected for the bend specimens, because it provided sufficient width to include all of the weld metal and heat-affected zone in the welded bend specimens.

Testing Procedure

The tension test specimens were tested in a Baldwin Southwark testing machine. Initial rate of loading was 0.03 ipm. Shortly after the observations indicated that the yield had been reached, the rate was decreased to allow accurate reading of deflection on a Baldwin Southwark strain indicator. The values for the tension test results given in the tables are averages for three to five specimens.

The bend specimens were tested by placing them on a bend die and using punches of various nose radii to bend the specimens. A series of dies with nose radii from $1^1/_2$ in. to a sharply machined edge were used. The bend-test results are reported in terms of the minimum die radius to which the specimen bent before a crack occurred. To make it possible to compare the ductility of the various thicknesses of sheet, the minimum die radii are reported in terms of sheet thickness. This method of reporting is used because a 2T bend, for example, denotes about the same elongation in the outermost fibers for all sheet thicknesses. The values for bend-test results given in the tables are averages for 5 to 10 specimens.

Tests of Spot Welds

Spot-welded specimens were tested in tension shear and in cross tension. The specimens used for these tests are shown in Fig. 4. The tension-shear specimens were tested by pulling them in a tension machine without making corrections for the bending moment introduced by the nonlinear loading of the specimen. The tension specimen was tested using the jig shown in Fig. 6. The strength values given for spot welds in the tables are averages for 5 to 10 specimens.

Hardness and Metallographic Specimens

Hardness tests were made on specimens cut from arc welds and spot welds. These same specimens were also used for metallographic studies. The specimen

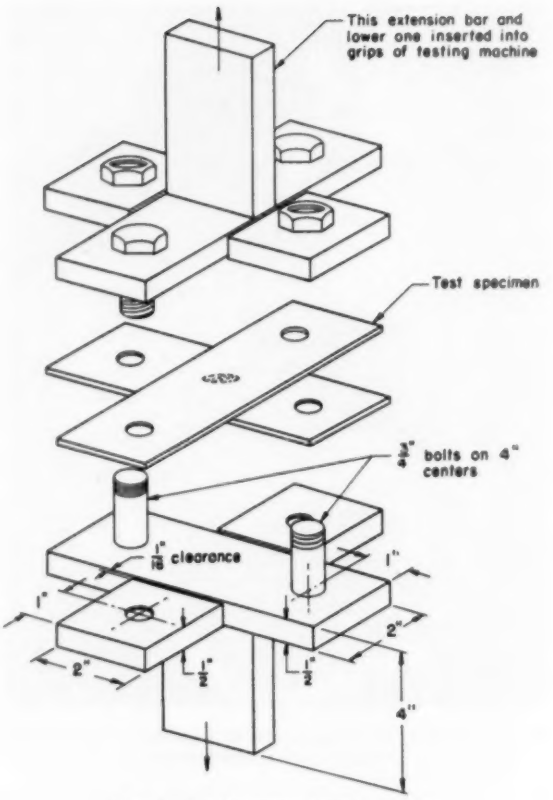


Fig. 6 Jig for cross-tension tests

was cut so that it contained weld metal, heat-affected zone on both sides of the weld metal, and unaffected base metal on both sides of the heat-affected zones. These specimens were mounted and polished metallographically. After the metallographic examination was completed, hardness surveys were made on the specimens.

PROPERTIES OF UNWELDED SHEET

The strength properties of all of the alloyed and unalloyed sheets used in this investigation were determined, and their metallurgical structures were studied.

Strength Properties of Titanium Sheet

The tensile and bend properties obtained on all of the sheet used in the investigation are given in Table 4. The comparison of the properties obtained from the alloys used in this investigation with those obtained from alloys made with iodide titanium is shown in Fig. 7. The strengths of the sponge alloys are higher than those of the iodide alloys, but this is to be expected. The sponge itself contains some carbon, oxygen and nitrogen, and from Table 4 it can be seen that the properties of the unalloyed sheet produced from

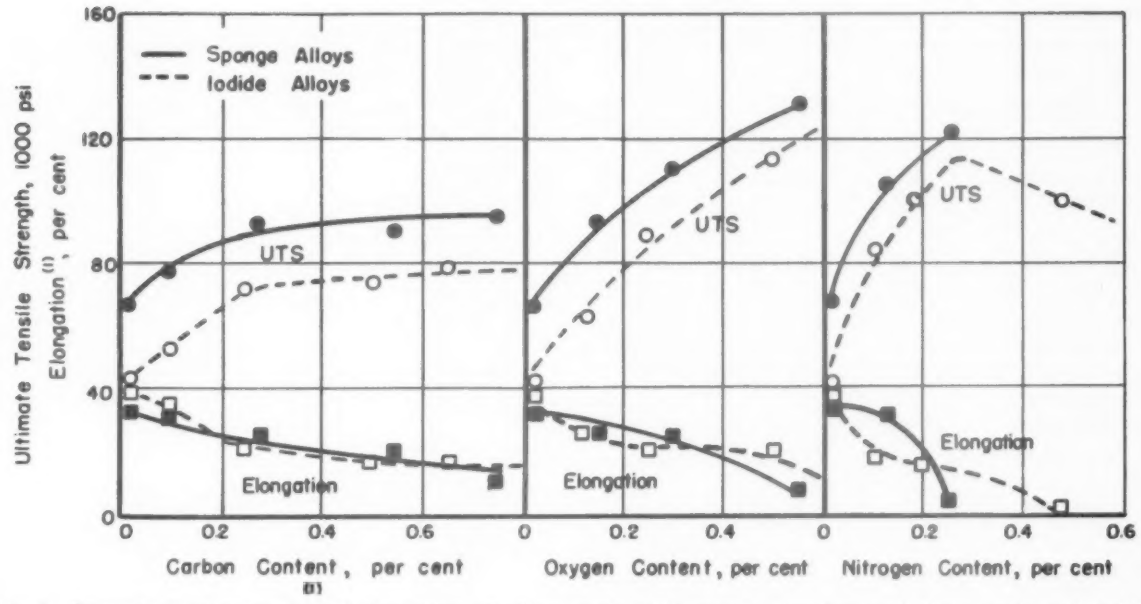


Fig. 7 Comparison of strength and elongation of alloys made with sponge titanium and alloys made with iodide titanium

(1) Elongation of sponge alloys, per cent in 2 in. Elongation of iodide alloys, per cent in 1 in.

Note: Iodide data from "Alloys of Titanium with Carbon, Oxygen, and Nitrogen," by R. I. Jaffee, H. R. Ogden, and D. J. Maykuth, *Jnl. Metals, Trans. AIME*, 188, 1261–1266 (October 1950).

sponge are considerably higher than the properties of the sheet produced from unalloyed iodide titanium. In general, the strength and ductility of each sponge alloy differ from the strength and ductility of the comparable iodide alloy by a consistent amount.

It can be easily seen from consideration of the data given in Table 4 and Fig. 7 that oxygen and nitrogen have a much greater effect upon the properties of titanium than does carbon. This is particularly true with respect to ductility. In alloys of oxygen and nitrogen, the ductility drops off rapidly as the amount of alloying element increases. At a rather low level, the ductility becomes nearly zero. With carbon, the ductility drops off somewhat, but does not become zero.

Structures of Base Plate

The structures of the iodide and Process A sheets in the rolled and stress-relieved condition consist of

Fig. 8 Typical annealed structure of titanium sheet used in this investigation except those containing 0.28% or more carbon

Dark line markings are titanium hydride. × 250.

Fig. 9 Typical annealed structure of titanium sheet used in this investigation containing 0.28% or more carbon

Gray equiaxed constituent is carbide. Photomicrograph is of 0.74% carbon alloy. × 250.

Table 4—Strength Properties of Unalloyed and Alloyed Titanium Sheet

Composition	Sheet Thickness, in.	Yield Strength, psi, 0.2% offset	Tensile Strength, psi	Elongation in 2 in., per cent	Reduction of Area, per cent	Minimum Bend Radii[1]		Average Hardness, Vickers
						Longitudinal	Transverse	
Iodide	0.064	24,000	43,400	53	67	< 1T	< 1T	101
Unalloyed Sponge (Process A)	0.032	46,400	67,200	34	43	1T	1T	
	0.064	45,700	66,900	30	44	1/2T	1T	161
	0.125	45,100	66,700	35	46	1-1/2T	4T	
0.13% Carbon	0.032	55,900	74,000	31	42	1-1/2T	1-1/2T	
	0.064	62,800	76,200	34	48	1T	1T	177
	0.125	61,900	75,700	33	44	2T	1-1/2T	
0.28% Carbon	0.032	74,800	89,200	28	37	2T	2T	
	0.064	77,400	91,300	24	33	2-1/2T	1-1/2T	253
	0.125	77,000	90,800	24	33	3T	2T	
0.55% Carbon	0.032	75,000	89,000	11	21	3T	2T	
	0.064	76,300	98,700	21	33	4T	6T	243
	0.125	72,600	90,100	20	33	2T	4T	
0.74% Carbon	0.032	93,400	110,600	7	5	6T	8T	
	0.064	78,100	94,200	8	12	6T	8T	238
	0.125	92,000	95,700	10	21	4T	4T	
0.15% Oxygen	0.032	79,300	91,700	22	41	3T	2T	
	0.064	81,600	93,400	23	40	3T	2T	233
	0.125	84,000	92,700	26	40	2T	2T	
0.30% Oxygen	0.032	90,000	107,000	24	36	6T	4T	
	0.064	95,200	110,900	27	38	3T	8T	264
	0.125	99,200	111,300	25	38	12T	12T	
0.55% Oxygen	0.032	124,300	134,000	25	33	> 12T	> 12T	
	0.064	120,500	126,000	3	7	> 12T	> 12T	323
	0.125	121,700	131,000	8	10	> 12T	> 12T	
0.13% Nitrogen	0.032	92,000	105,000	26	40	2T	3T	
	0.064	98,300	112,000	20	39	3T	4T	239
	0.125	95,500	106,000	21	32	4T	6T	
0.24% Nitrogen	0.032	111,000	118,000	19	5	3T	> 12T	
	0.064	113,000	118,000	28	4	5T	> 12T	278
	0.125	--	127,000	0.5	4	> 12T	> 12T	
0.50% Nitrogen	Could not be rolled to desired sheet thickness.							384

(1) Minimum punch radius over which sheet could be bent without cracking. T = sheet thickness; 1T is about 30% elongation, 12T is about 4% elongation.

rather small equiaxed alpha grains. The 0.13% carbon alloy has a structure which also consists of equiaxed alpha grains. However, in the 0.25% carbon alloy a few equiaxed carbide particles can be found. In the 0.55 and 0.75% carbon alloys, there is quite a bit of the equiaxed carbide to be found in the microstructure. All of the oxygen and nitrogen alloys have equiaxed alpha structure in the rolled and stress-relieved condition. The structures of the rolled and annealed sheets are shown in Figs. 8 and 9.

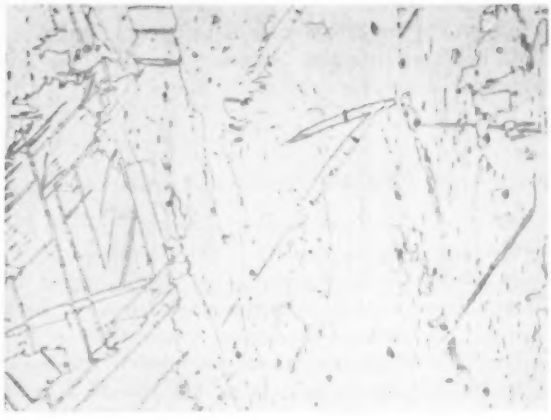
PROPERTIES OF WELDMENTS IN TITANIUM

Unalloyed Iodide Titanium

The properties of arc welds in the iodide titanium sheets are given in the following tabulation:

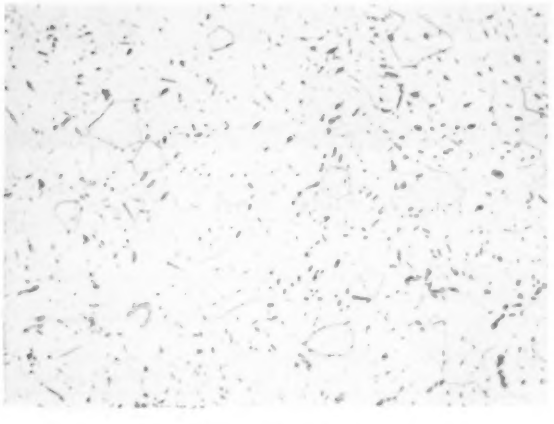
	Yield strength, psi	*Ultimate tensile strength, psi*	*Elongation in 2 in., %*	*Reduction of area, %*	*Minimum bend radius*	
					Longitudinal	*Transverse*
Unwelded	24,000	43,400	53	67	<1T	<1T
Welded	....	43,100	34	55	1T	<1T

Properties of the unwelded sheet are included for comparison. It can be seen from this tabulation that



Weld

Heat-affected zone



Unaffected base plate

there is little difference between the properties of the iodide titanium weldments and the unwelded sheet. The welds are somewhat stronger than the base metal, and fractures in the welded tension specimens occur in the base metal. Because of this, the elongation over 2 in. is somewhat lower for the welded specimens than for the unwelded specimens. This was found to be true for all of the transverse tensile specimens tested during this investigation except those which were very brittle and fractured through the weld. The results of the bend tests indicate that the ductility of the weld itself in the iodide sheet is approximately the same as the ductility of unwelded sheet.

The structures present in the welded sheet are shown in Fig. 10. As can be seen from this figure, the weld consists of rather large alpha grains. That portion of the heat-affected zone which has been heated above the alpha-to-beta transformation temperature also consists of large alpha grains. The acicular alpha which appears in the welds is probably caused by oxygen contamination during welding. This is the type of Widmanstätten precipitation which forms the so-called "basket weave" structure in titanium. In the weld shown in Fig. 10, the contamination has been very slight. The hardness of this weld was only 10 VHN higher than that of the sheet.

The properties of spot welds in the 0.064-in. iodide titanium sheet are given in the following tabulation:

Tension-shear strength, lb	1875
Cross-tension strength, lb	1050
Tension-shear ratio	0.56
Maximum Vickers hardness in weld	133

These values were obtained from specimens having $3T$ spot diameters (T is sheet thickness).

Unalloyed Process A Titanium

The properties of arc welds in unalloyed Process A titanium sheet are given in Table 5. The results of tests made on the Process A sheet in the controlled-atmosphere chamber show that there is little difference between the properties of the arc weldments and the unwelded sheet. Again, the tensile ductilities of the arc-welded specimens were somewhat lower than those of unwelded sheet, but this was due to the method of failure of the sheet. Necking down and failure occurred

Fig. 10 Structures found in different zones of arc weld in iodide titanium sheet. $\times$ ***250***

Table 5—Strength Properties of Arc Welds in Unalloyed Sponge Titanium Sheet

Type of Titanium	Sheet Thickness, in.	Tensile Strength, psi	Elongation in 2 in., per cent	Reduction of Area, per cent	Minimum Bend Radii		Maximum Hardness, Vickers
					Longitudinal	Transverse	
Sponge (Process A)	0.064	70,800	22	37	3T	1-1/2T	209
Welded in Argon Chamber	0.125	69,500	21	41	1-1/2T	2T	219
Sponge (Process A)	0.064	71,100	19	40	4T	4T	256
Welded in Air	0.125	68,000	23	44	12T	4T	222

outside of the weld, and, consequently, this reduced the over-all elongation in 2 in. in the specimen. The bend-test results indicate that there is no great difference between the ductility of the weld and that of the unwelded sheet.

For those welds made in the open air, the story is somewhat different. Here, contamination by oxygen and nitrogen during welding has affected the properties of the weldment. As can be seen from Table 5, the bend ductilities of weldments made in the open air are lower than those of weldments made in the controlled-atmosphere chamber. They are also lower than the bend ductility of unwelded sheet.

The properties of spot welds in the unalloyed Process A titanium sheet are given in the following tabulation:

Sheet thickness, in.	*Spot diameter*	*Tension-shear strength, lb*	*Cross tension strength, lb*	*Tension-shear ratio*	*Maximum hardness, Vickers*
0.032	5*T*	1090	445	0.41	220
0.064	3*T*	2400	900	0.37	222

As was the case with the spot welds in the iodide sheet, the spot welds in the sponge sheet appear to have considerable ductility. The ratio of tension-shear to cross-tension tests is fairly high, and this is some indication both of good ductility and low-notch sensitivity.

The metallographic structures of both arc and spot welds made in the unalloyed Process A titanium sheet were not much different from those that were found in the iodide sheet. Both weld and heat-affected zones in the unalloyed sponge sheet contain more of the alpha structure, which is known as "basket-weave" structure, than welds in iodide sheet. This basket-weave structure can be caused by oxygen and is probably indicative of the difference in purity between the Process A titanium and the iodide titanium. Figure 11 shows cross sections of spot welds in the Process A titanium sheet. The thing which is most noticeable in this macrograph is the extent of penetration of the welds. This has been noticed by other investigators[1] and apparently is to be expected when spot welding titanium. These cross sections are typical of spot welds in all of the alloys.

0.032-In. sheet

0.064-In. sheet

Fig. 11 Cross sections of spot welds in 0.032- and 0.064-in. unalloyed sponge titanium (Process A) sheet. × 8

Properties of Welded Titanium-Carbon Alloys

The properties of arc welds in alloys of titanium and carbon are given in Table 6. The properties of the arc weldments in alloys containing 0.13% carbon are about the same as those of the unwelded alloy sheet. However, for alloys containing more than 0.13% carbon, the properties of the arc-welded specimens differ considerably from those of the unwelded sheet.

Table 6—Strength Properties of Arc Welds in Sponge Titanium-Carbon-Alloy Sheet

Composition	Sheet Thickness, in.	Tensile Strength, psi	Elongation in 2 in., per cent	Reduction of Area, per cent	Minimum Bend Radii		Maximum Hardness, Vickers
					Longitudinal	Transverse	
Unalloyed Sponge (Process A)	0.064	70,800	22	37	3T	1-1/2T	209
	0.125	69,500	21	41	1-1/2T	2T	210
0.13% Carbon	0.064	81,700	23	39	4T	3T	235
	0.125	76,900	19	41	2T	4T	243
0.28% Carbon	0.064	93,800	24	19	8T	> 12T	251
	0.125	98,700	19	36	4T	12T	251
0.55% Carbon	0.064	92,300	2	9	12T	> 12T	242
	0.125	90,600	3	3	> 12T	> 12T	274
0.74% Carbon	0.064	95,500	1	2	> 12T	> 12T	260
	0.125	92,600	1	5	> 12T	> 12T	285

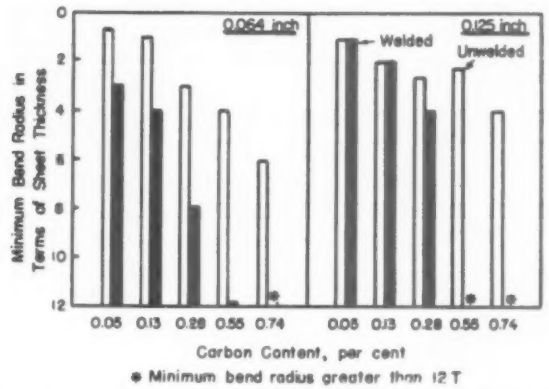
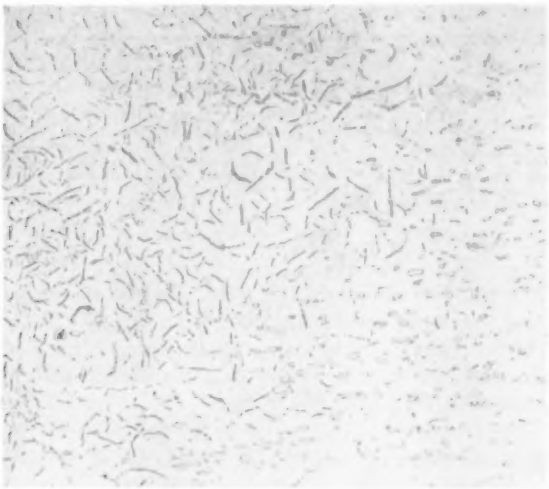


Fig. 12 Comparison of bend ductilities of arc-welded and unwelded titanium-carbon alloy sheets



100 × Weld (*left*) and heat-affected zone (*right*)

250 × Weld

Fig. 13 Structures which occur in weld zone of titanium–0.74% carbon-alloy sheet

The 0.25% carbon weldments have about the same tensile properties as do the unwelded sheet. However, the bend-test results for weldments in this alloy differ somewhat from the bend-test results for unwelded sheet. The fracture occurs at lower elongations in the welded sheet than in the unwelded sheet. In addition, this sheet was the only one tested in which fracture in the bend test occurred in the heat-affected zone rather than in the weld.

In the alloys containing 0.55 and 0.74% carbon, both the tensile and bend properties are different in the weldments than in the unwelded sheet. The tensile strength is about the same for the weldments, but the ductility has been greatly reduced by welding. This reduction in ductility is also shown in the bend tests, and a comparison of the bend ductilities of welded and unwelded sheets shows this very definitely. Such a comparison is given in Fig. 12.

The cause of the embrittlement of the higher carbon alloys is the formation of a carbide network in the weld during freezing. Hitchcock and Mahla have also related brittleness at high carbon contents with the occurrence of the carbide.[2]

The photomicrograph in Fig. 13 shows the carbide structure which was found in an arc weld in 0.74% carbon-alloy sheet. The change in equiaxed carbide inclusions which are present in the unaffected base metal and heat-affected zone of a weld to the network which is present in the weld is shown in the upper photomicrograph. The other photomicrograph shows

Fig. 14 End of crack in partially fractured arc-welded bend specimen in titanium–0.55% carbon-alloy sheet. × 500

the carbide network structure in the weld itself at higher magnification.

Examination of a number of bend specimens cut from welded sheets of the 0.55 and 0.74% carbon alloys has shown that fractures and cracks in these bend specimens tend to follow the carbide network. This is shown in Fig. 14. This figure shows the end of a major crack which occurred in a weld during bend testing. It can be seen that the crack has followed the carbide, sometimes splitting the carbide inclusion into two parts. It can also be seen that some of the other carbides have cracked.

When the carbon content is high enough to be above the solid-solubility limit of carbon in the alpha titanium, heat treatment will not affect the ductility of the weldment except possibly by spheroidizing the carbides. However, with lower carbon content alloys, the 0.28% alloy, for example, heat treatment may affect the amount of carbide present in the weld. In this alloy, welds contain the stringer-type carbide which is found in welds in the higher carbon alloys. Of course, there is much less of it than is found in welds in the 0.55 and 0.74% alloys. These carbides precipitate out during freezing and the cooling rate is fast enough to prevent their being taken into solution in the alpha titanium. As can be seen from the phase diagram in Fig. 15, the carbide has low solubility in beta titanium. Consequently, a quench from temperatures in the beta field produces alpha which is not saturated with carbon even when the carbon content is near the limit of solid solubility. Heat treatments at temperatures high in the alpha field saturate the alpha with carbon and increase its hardness and strength. The hardness of the weld metal in 0.28% carbon sheet is raised by 30 to 50 Vickers by being heated at 1500° F for 4 hr after welding. On the fully annealed base metal, such a treatment has no effect on hardness. This treatment does not affect the ductility of the weldment appreciably. Even in the as-welded condition the 0.28% alloy weld contains only a few carbide stringers, and removal of these by heat treatment has little effect on ductility of the weldment. It does, however, shift the place where fracture occurs in a bend specimen from the base metal to the weld. In the as-welded bend specimen the base metal is harder (20 to 25 Vickers) than the weld and is less ductile. After heat treatment the weld is harder than the base metal and consequently is less ductile.

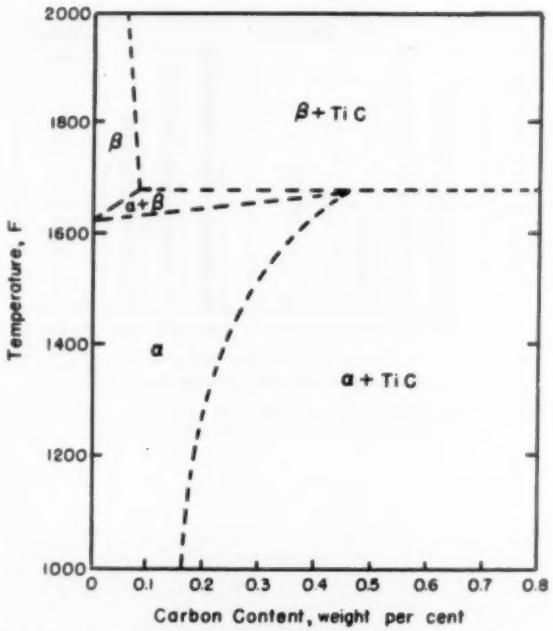


Fig. 15 Part of tentative equilibrium diagram for titanium-carbon alloys

Note: From paper on "Alloys of Titanium with Carbon, Oxygen, and Nitrogen," by R. I. Jaffee, H. R. Ogden, and D. J. Maykuth, *Jnl. Metals, Trans.* AIME, 188 (October 1950).

The properties of spot welds in the titanium-carbon-alloy sheets are given in Table 7. So far as tension-shear strengths are concerned, carbon in amounts as high as 0.55% had little effect. However, the cross-tension strength starts to decrease at a carbon content of 0.28%. In sheets containing 0.55% carbon or more, the cross-tension strength becomes very low, and, consequently, the tension-shear ratio becomes very low.

Table 7—Strength Properties of Spot Welds in Sponge Titanium-Carbon Alloys

Composition	Sheet Thickness, in.	Nugget Diameter	Tension-Shear Strength, lb	Cross-Tension Strength, lb	Tension-Shear Ratio	Maximum Hardness, Vickers
Unalloyed Sponge	0.032	5T	1100	500	0.45	240
0.03% Carbon	0.064	3T	2400	900	0.37	222
0.13% Carbon	0.032	5T	1250	525	0.42	268
	0.064	3T	2500	1500	0.60	249
0.28% Carbon	0.032	5T	1000	300	0.30	330
	0.064	3T	2600	800	0.31	306
0.55% Carbon	0.032	5T	1100	200	0.18	314
	0.064	3T	2400	300	0.13	294
0.74% Carbon	0.032	5T	1000	40	0.04	345
	0.064	3T	1600	300	0.19	314

Table 8—Strength Properties of Arc Welds in Sponge Titanium-Oxygen-Alloy Sheet

Nominal Composition (Addition made during melting)	Sheet Thickness, in.	Tensile Strength, psi	Elongation in 2 in., per cent	Reduction of Area, per cent	Minimum Bend Radii		Maximum Hardness, Vickers
					Longitudinal	Transverse	
Unalloyed Sponge (Process A)	0.064	70,800	22	37	3T	1-1/2T	209
	0.125	69,500	21	41	1-1/2T	2T	210
0.15% Oxygen	0.064	96,000	10	24	3T	2T	283
	0.125	96,900	15	24	4T	3T	279
0.30% Oxygen	0.064	101,000	12	15	12T	> 12T	339
	0.125	109,000	10	14	> 12T	> 12T	345
0.55% Oxygen	0.064	103,000	0	2	> 12T	> 12T	363
	0.125	125,000	1.5	1	> 12T	> 12T	339

The reason for the drop in the cross-tension strength with increasing carbon content appears to be the network carbides which are present in the weld. This is the same type of structure as was found in arc welds in the higher carbon alloys except that in the spot welds it is much finer. Figure 16 shows the appearance of the carbide in a spot weld in 0.55% carbon sheet. The carbide embrittles the weld and the cross-tension specimens fracture with much less deformation than is obtained with the spot welds which do not contain carbides. Generally, the spot-weld specimens in the high-carbon alloys shatter when they break during testing.

Properties of Welded Titanium-Oxygen Alloys

The strength properties of arc-welded titanium-oxygen alloys are given in Table 8. The addition of 0.15% oxygen to titanium has no bad effects on the properties of arc welds. The tensile strength of weldments is raised and the tensile elongation is somewhat lower than for the unwelded sheet. This is due to the higher strength of the weld, which forces nearly all of the deformation to occur in the heat-affected zone and unaffected base metal. The bend ductility of the welded 0.15% oxygen sheet is about the same as for unwelded sheet and is not too much lower than that of weldments in unalloyed sponge sheet.

For oxygen contents of 0.30%, the story is quite different. Welds in the alloy have much lower bend ductilities than unwelded sheet of the same composition. This is not caused by any difference in structure that occurs in the weld, as was the case with the carbon alloys. The welds in the 0.30% oxygen-alloy sheet contain numerous small cracks as-welded and these appear to be the cause of the low bend ductility. Figure 17 shows a crack in a weld made in $^1/_8$-in. titanium–0.30% oxygen sheet. The same type of crack can also occur in the heat-affected zone and in the unaffected base metal, as is shown in Fig. 18. These cracks are not present in the base metal before welding. They do not appear to be associated with any structural factors although they might be caused by segregation of oxygen, particularly in the weld metal. The cracks may also be caused by some type of hot shortness in the higher oxygen alloys.

Welds in the 0.55% oxygen alloy have very low ten-

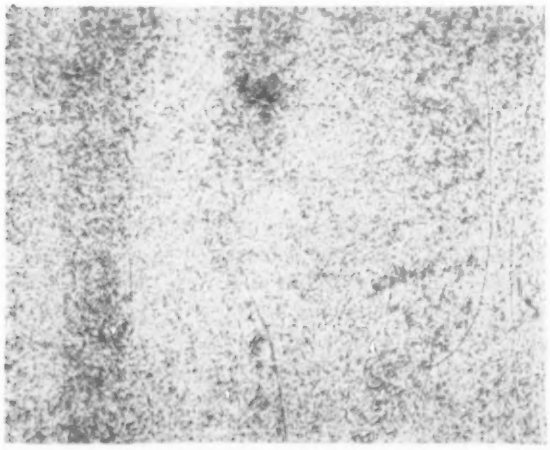


Fig. 16 Area in spot-weld nugget in titanium–0.55% carbon alloy. Acicular structure is carbide network. × 200

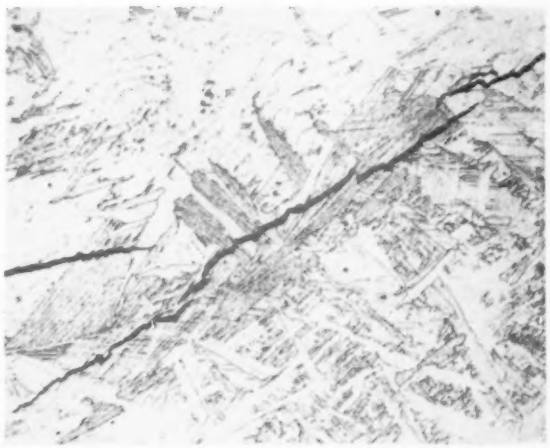


Fig. 17 Crack in weld metal in tungsten arc weld in titanium–0.30% oxygen alloy sheet. × 200

Table 9—Properties of Spot Welds in Sponge Titanium-Oxygen Sheet

Composition	Sheet Thickness, in.	Spot Diameter, in.	Tension-Shear Strength, lb	Cross-Tension Strength, lb	Tension-Shear Ratio	Maximum Hardness, Vickers
Unalloyed Sponge (Process A)	0.032	5T	1100	500	0.45	240
	0.064	3T	2400	900	0.37	222
0.15% Oxygen	0.032	5T	1150	300	0.26	268
	0.064	3T	2600	1200	0.46	285
0.30% Oxygen	0.032	5T	1100	140	0.13	333
	0.064	3T	2800	900	0.32	336
0.55% Oxygen	0.032	5T	525	0	0	390
	0.064	3T	1250	60	0.05	363

Fig. 18 Crack in unaffected base metal just outside heat-affected zone of weld in titanium–0.30% oxygen-alloy sheet. × 200

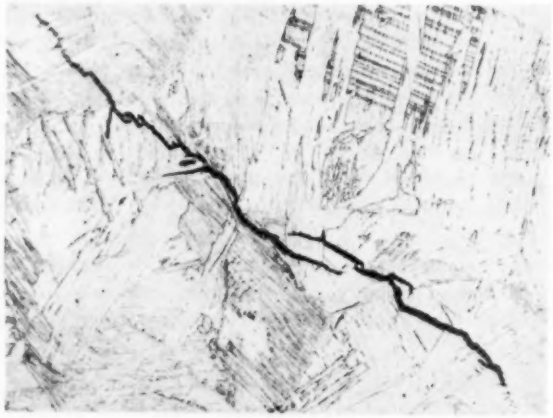


Fig. 19 Cracks in weld-metal in arc weld in titanium–0.13% nitrogen alloy. × 75

Table 10—Strength Properties of Arc Welds in Sponge Titanium-Nitrogen-Alloy Sheet

Composition	Sheet Thickness, in.	Tensile Strength, psi	Elongation in 2 in., per cent	Reduction of Area, per cent	Minimum Bend Radii		Maximum Hardness, Vickers
					Longitudinal	Transverse	
Unalloyed Sponge (Process A)	0.064	70,800	22	37	3T	1-1/2T	209
	0.125	69,500	21	41	1-1/2T	2T	210
0.13% Nitrogen	0.064	113,000	13	16	8T	>12T	306
	0.125	105,000	8	9	12T	12T	322
0.24% Nitrogen	0.064	120,000	0	0	>12T	>12T	317
	0.125	120,000	0	0	>12T	>12T	360

sile and bend ductility. Here again the cause seems to be cracks in the weld and base metal near the weld zone. Welds in this alloy contain many more cracks than welds in the 0.30% oxygen alloy.

The results of spot-weld tests in the titanium-oxygen-alloy sheet are given in Table 9. Oxygen does not have an adverse effect on tension-shear load until the amount present is somewhat greater than 0.30%. The effect on cross-tension strength was noticeable in the 0.032-in. sheet at 0.15% oxygen. In the 0.064-in. sheet, however, it was not particularly noticeable except in the 0.55% oxygen sheet. The welds in both thicknesses of sheet had about the same hardnesses and no cracked welds were found in the samples which were metallographically examined. Apparently the difference in behavior between the spot welds in the two sheet thicknesses was caused by the different geometry of the spots. As can be seen from the table, the spot weld is larger in terms of sheet thickness in the thinner sheet. It was necessary to use the proportionally larger spot in the thinner sheet to obtain consistent strength values.

Fig. 20 Photomacrograph of arc weld in 1/8-in. titanium–0.24% nitrogen-alloy sheet. × 7

Properties of Welds in Titanium-Nitrogen-Alloy

The strength properties of arc welds in titanium-nitrogen-alloy sheets are given in Table 10. It is apparent that nitrogen affects the properties of welds in titanium at much lower levels than either carbon or oxygen. Welds in sheet containing 0.13% nitrogen have poor bend ductility. As in the oxygen alloys, cracks in the weld such as shown in Fig. 19 appear to be the cause of the poor bend ductility. In the 0.24% nitrogen alloy, the weld, heat-affected zone and the unaffected base metal adjacent to the heat-affected zone contain cracks. This is shown in Fig. 20. There was no indication that the sheets of either of these alloys contained cracks prior to welding.

The properties of spot welds in the titanium-nitrogen-alloy sheets are given in Table 11. As in the arc-welded specimens, the properties of spot welds in sheet containing 0.13% nitrogen are rather poor. This is particularly shown by the tension-shear ratio. The low cross-tension strengths obtained with the nitrogen alloys does not appear to be caused by cracks in the spot welds. It, apparently, is a result of the low ductility which is a property of the alloys.

POROSITY IN ARC WELDS IN TITANIUM

Examination of radiographs of arc welds made during this investigation has shown that porosity can be a problem in titanium welds. Figure 21 shows a typical example of a porous weld in one of the titanium-alloy sheets. There seemed to be no correlation between alloy content and porosity. There was some correlation between sheet thickness and porosity, most porosity occuring in 1/8-in. sheet. It was possible to decrease porosity by using higher welding currents or slower welding speeds.

The suspected cause of porosity in titanium welds is hydrogen. Other gases which might be encountered react so readily with titanium that it is difficult to see how they could cause porosity. Hydrogen is known to have a fairly low solubility in beta titanium. If the solubility of hydrogen is high in liquid titanium, rejection during freezing as a gas could cause porosity.

CONCLUSION

Carbon, oxygen and nitrogen can cause brittleness in welds in titanium when present in sufficient amounts.

Table 11—Strength Properties of Spot Welds in Sponge Titanium-Nitrogen-Alloy Sheet

Composition	Sheet Thickness, in.	Spot Diameter, in.	Tension-Shear Strength, lb	Cross-Tension Strength, lb	Tension-Shear Ratio	Maximum Hardness, Vickers
Unalloyed Sponge (Process A)	0.032	5T	1100	500	0.45	240
	0.064	3T	2400	900	0.37	222
0.13% Nitrogen	0.032	5T	800	220	0.28	351
	0.064	3T	2750	400	0.15	330
0.24% Nitrogen	0.032	5T	1000	33	0.03	333
	0.064	3T	2100	300	0.14	346

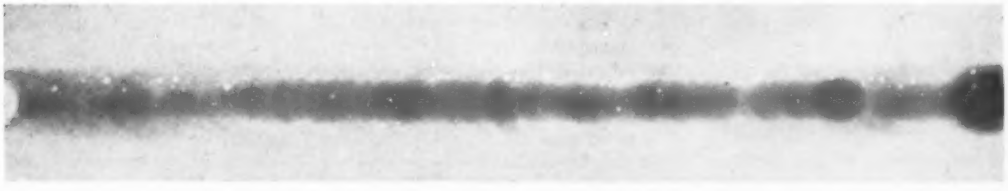


Fig. 21 Example of porosity obtained in arc weld in 1/8-in. titanium sheet

To avoid brittle welds, carbon and oxygen should be kept below the following amounts: Carbon, 0.28%; oxygen, 0.15%. The data show that 0.13% nitrogen is enough to produce poor properties in welds in titanium sheet. Unfortunately, it is not possible to say just what the maximum nitrogen content should be. Information is needed on the properties of welds in sheet containing 0.05 to 0.10% nitrogen to determine the maximum tolerable amount. An estimate of the maximum nitrogen content based on the available data is 0.05%, but additional work is needed to determine whether this estimate is correct.

The adverse effects of the these elements occur at relatively low concentrations. This points out the necessity for maintaining good shielding during welding. It is known that as much as 0.20% nitrogen can be picked up when multipass tungsten-arc welds are made with shielding which appears to be normal but is apparently inadequate. Consequently, the use of trailing shields and gas backups is recommended when titanium is to be welded.

ACKNOWLEDGMENT

All of the sheet used in this investigation was melted and fabricated at Battelle Memorial Institute. This part of the work was carried out by John G. Kura, Morris W. Mote, Jr., and William J. Lepkowski. Preparation of the sheet for welding tests and the tests of arc weldments and spot welds were planned and done by A. L. Northway and W. H. Kearns. All of the inert-gas-shielded tungsten-arc welding was done by John F. Dethloff. The investigation was made under the supervision of C. B. Voldrich and his aid and advice in preparation of this paper is gratefully acknowledged.

Acknowledgment is due Major R. E. Bowman and Dr. H. K. Adenstadt of the Materials Laboratory at Wright-Patterson Air Force Base for their interest and assistance.

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Netherlands Welding Society

Translated by Dr. G. E. Claussen

The annual report of the Netherlands Welding Society for the period July 1, 1951 to July 1, 1952 shows an increase of 260 in membership during the period to a total of 5488. The Society has 38 sections in all the principal towns and cities of the Netherlands and publishes a monthly welding magazine. It continued its work in conducting examinations for arc and gas welders and welding instructors. It also organized 12 welding courses of different types.

The Research Committee of the Society has been particularly active. It cooperated with the Welding Research Council in discussing reviews of literature, particularly on stainless steel, with the British Welding Research Assn. in shear tests, and with the combined Belgian-Netherlands Steel Committee. The Research Committee has seven subdivisions:

1. Weldability. A static notched-bend test and a V-notch Charpy test are favored for studying transition temperature.

2. Alloy Steels. The Doan-Stout system is being applied to study the effect of welding variables on maximum hardness in welding chromium-molybdenum steels.

3. Welded structures. Besides a study of impact strength of mild steel welds made with 6015 and 6020 electrodes, a group is investigating the relative effect of defects in welded high-pressure piping in cooperation with the British Welding Research Assn. The British are using mild steel pipes 6 in. OD, $^3/_8$-in. wall with pulsating oil pressure. The Netherlands group uses pipe 4 in. OD, 0.20-in. wall under static oil pressure with superimposed axial pulsating pressure. Three types of V-butt welds are being studied: (*a*) no backing, (*b*) conical backing ring, (*c*) AWS type ring. Low-tensile 6015 electrodes are being used, and the welds are not machined. Unwelded pipe is tested for comparison. The Shell Laboratories in Amsterdam are testing welded nozzles under three conditions: (*a*) nozzle welded to a flat plate, (*b*) nozzle welded to a curved plate and (*c*) nozzle welded in a boiler. Strain gages are used to measure tangential shrinkage. Similar tests are being made to measure the stress distribution in the vicinity of eccentric connections to pressure vessel heads.

4. Defects in Welds. A large number of test welds in $^3/_8$-in. plates with various types of defects are being radiographed. The X-ray picture of each weld is mounted on a punched-hole card (ASM system) together with photographs of top and bottom of weld, and of four etched cross sections. All cards illustrating defects of a given type can be removed readily from the file for comparison with new X-ray pictures. The classification of defects follows the system devised by Committee V of the International Institute of welding.

5. Gas Welding. The effect of heat treatment on mechanical properties of gas welds is being investigated.

6. Nonferrous Metals. Corrosion tests of welded aluminum alloys will be conducted in sea water, in sea air, in brackish water, in rural air and in an industrial atmosphere. Sea water exposure will be at Gothenburg, Sweden, and in Spain. The following specimens will be tested: 52S welded with 52S; 56S welded with 56S; 51S welded with 43 and 51S welded with 52S. Four welding processes will be used: gas, arc, sigma and argonarc. The 52 and 56 alloys will be tested rolled and extruded. The specimens will be 8 in. square, 0.20 in. thick. Material will be obtained from four different countries: England, Switzerland, Germany and Netherlands. Some specimens of 61S, 75St and 41S will be included. After the corrosion test is completed, the mechanical properties and metallographic structure will be investigated. The mechanical properties of welds in thick sections of 52S and 56S are being determined.

7. Resistance Welding. The determination of optimum conditions for spot and seam welding black steel sheet was suggested as a suitable topic for research after a canvass of the metal industry. Afterward, the interest of industry in the research turned out to be so small that only a survey of literature will be undertaken.

The Weldability of Austenitic Manganese Steels

by F. Danhier

SUMMARY

THE poor weldability of many Hadfield steels is caused principally by intergranular microfissures in the heat-affected zone directly beneath the weld bead. The thermal cycle of welding being brief, the austenite is stable and carbide precipitation has scarcely any effect on the ductility of the heat-affected zone. Hadfield steels of the following compositions have good weldability:

Wrought	*Cast*
Mn over 12.5%	Over 12.5%
C less than 1.20%	Less than 1.10%
P 0.035% max	0.030% max
Si less than 0.25%	Less than 0.45%

Copper-alloy gas welding rods or electrodes should not be used on these steels.

Hadfield steels contain 10.5–14% Mn and 0.8–1.6% C with up to 1.5% Si, 0.15% P, and 0.04% S. Some special varieties generally low in carbon contain up to 3% Cr, 5% Ni, or 1% Mo. They always are heat treated by water quenching from 1920 F. Reheating for long periods in the range 660–1650 F precipitates carbides in the grain boundaries and lowers the ductility, particularly with over 1.2% C.

Austenitic 13% Mn electrodes are used widely for rebuilding surfaces, but are not used for joint welding because visible cracks appear in the beads. Crackfree welds can be made with austenitic chromium-nickel electrodes, but the joints fail in bend tests after a few degrees. Fracture follows the fusion zone. If, as some say, the brittleness is due to martensite or carbide precipitation in the heat-affected zone, Hadfield steels, as a class, would be unsuitable for welding. The thermal cycle of welding transforms the unstable austenite to a brittle condition. Experiment has shown that this is not true.

First of all, a weld metal containing 13% Mn, 0.9% C, 86% Fe has been developed which can be bent to an elongation of over 50% without cracking. Four layers of the $^5/_{32}$-in. electrode are deposited on a bar of 18.8 stainless steel $^5/_{16} \times {}^3/_4 \times 6$ in. using 150 amp a c. After each pass the specimen is allowed to cool in air to 212° F. The final thickness of the specimen is nearly 1 inch and the last pass is ground lightly. The specimen is bent 180° around a $^3/_4$-in. pin without cracking. This electrode and an austenitic electrode depositing metal containing 24% Cr, 12% Ni, 0.12% C, 3% Mo have been used for weldability studies. The latter electrode is called Electrode G; its structure contains a dendritic pattern of ferrite.

The weldability test consists of depositing a bead with an a c electrode on the steel to be studied. The structure of a section through the bead is examined under the microscope. Examination of many specimens shows that most retain their austenitic structure throughout the heat-affected zone. Very often intergranular microcracks are observed in the zone. The cracks are responsible for poor weldability. It is possible that the grain boundaries contain discontinuous films of silicates, fragile carbides, phosphorus-rich eutectics, or other eutectics of low melting point. These films, being liquid after the bead solidifies, permit the grains to be pulled apart by shrinkage stresses.

EFFECT OF CARBON

We have never found any indication of carbide precipitation in the heat-affected zone of steels containing less than 1.1% C. Precipitated carbides have been observed in the HAZ of a cast steel containing 1.5% C. Preheat, therefore, is not desirable for steels with over 1.1% C.

EFFECT OF SILICON

Within the usual range of 0.20–0.50%, silicon seems to have little effect. Higher silicon accentuates the bad effect of high phosphorus. Two effects may be produced by silicon: 1. films of silicate may form around some grains, or 2. an intergranular phase of low melting point may be formed, such as the eutectic FeSi – Fe_3P – Fe melting at 1860 F.

EFFECT OF PHOSPHORUS

We believe phosphorus to be chiefly responsible for microcracks. The solubility of phosphorus in austenite is extremely small in the presence of carbon and other alloying elements. As a matter of fact, phosphorus is practically insoluble in the austenite of Hadfield steel with 1% C. The steel may pick up 0.15% P from the

Abstract of "La Soudabilité des Aciers Austenitiques au Manganèse," published in Arcos, No. 126, 3203–3217, July 1952. The author is Chief Engineer of S. A. Arcos, Brussels, Belgium. (Abstracted by Dr. G. E. Claussen.)

ferromanganese. The phosphorus probably exists as ternary or quaternary eutectic, although the microscope at 800× has never revealed the phase clearly. The melting points of some known eutectics are: Fe – Fe_3P = 1920 F (10.5% P); Mn – Mn_3P = 1765 F (5.5% P); Ni – Ni_3P = 1615 F; Fe – Mn – S = 1850 F; Fe Si – Fe_3P – Fe = 1860 F; Fe_3C – Fe_3P – Fe = 1740 F; Cu – Cu_3P = 1315 F; Cu – P – Zn = 1290 F and Fe_3C – Fe_3P – Fe = 1840F.

The well-known tendency of phosphorus to segregate to the center of the ingot enhances the possibility of eutectic formation. In castings the grains are large, the grain boundary area is small, and a small quantity of eutectic can do great damage. In wrought steel with smaller grains and more grain boundary area, the effect of the eutectic is less apparent. For this reason wrought steel has better weldability than castings.

The steels in Table 1 have been welded with $^5/_{32}$-in. manganese steel electrodes and have been examined for microcracks. Very few cracks were found in D. Cracks were rather frequent in E, and very numerous and large in F. The threshold for cracking appears to be 0.035% P for wrought steels, and 0.030% P for castings, at the level of 1% C, 0.30% Si, 13% Mn.

Table 1—Composition of Austenitic Manganese Steels in the Weldability Study

Steel	*P*	*Si*	*C*	*S*	*Mn*
B track casting	>0.13	...	...	...	...
C track casting	>0.12	...	>1.20	...	...
D rolled plate	0.037	0.34	0.80	0.023	14.15
E track casting	0.042	0.16	0.99	0.034	12.50
F cast plate	0.111	...	0.97	0.025	13.70
H track casting	0.096	0.48	1.02	0.033	13.63

EFFECT OF THE ELECTRODE

If a Hadfield steel is welded with an austenitic chromium-nickel steel Electrode G, most of the microcracks are filled with the stainless steel. This unexpected phenomenon is explained by the high fluidity of the stainless steel and by the very low surface tension of the high-phosphorus liquid.

A copper alloy electrode (96% Cu, solidus = 2010 F), when deposited on Hadfield steel, forms two layers, one rich in copper, the other rich in iron. The copper alloy penetrates deeply along the grain boundaries into the Hadfield steel. Even in torch brazing with a brass containing 40% zinc there is deep intergranular penetration, yet the brass melts at 1620 F and the brazed surface does not exceed 1740 F. With low-phosphorus steel there are only a few stringers of brass penetrating into the steel. With high phosphorus steel the stringers are very numerous. A brazed specimen of Steel D showed large cracks at a bend angle of 30° and total failure at 90°. The surface of the fracture showed that the brass penetrated several millimeters into the steel.

If the carbon content is below 1.1%, preheating is permissible to reduce distortion. Preheating for one hour at 750 F caused no precipitation or other change in steel E. However, since preheating increases the dilution of the weld metal by the relatively impure base metal, the weld metal is subjected to more severe conditions with preheating than without. If possible, the first layer or two should be deposited without preheat, subsequent layers being preheated where, for some reason, preheating is essential. The first layer also could be deposited with Electrode G.

A steel of good weldability can be oxygen cut without fear of cracking. The oxygen cut surfaces have good bend ductility.

The surfaces of Hadfield steel usually are decarburized to a depth of $^1/_2$ millimeter during heat treatment. The decarburized skin usually develops fine shallow cracks in a bend test. The decarburized skin was ground off all our specimens before welding.

Two weldability specimens may be used for Hadfield steels. In the Kommerell test a single bead of $^5/_{32}$-in. Electrode G is deposited on a plate $^5/_8$-in. thick. The bead is deposited down the center parallel to the long edges. With Steel D the specimen can be bent 180° without cracking. The Jackson-Luther weld bead nick-bend test also has been used with a plate $^3/_4$ in. thick. With Steel D bend angles of 24° and 25° were observed, the fractures being slow and silky.

Studies of the Crack Sensitivity of Aircraft Steels

Discussion by J. Koziarski

Messrs. Steinberger and Stoop should be congratulated for their systematic persistence in the research. This is the only one and right way for achieving success. An old military principle says: "Know first your enemy before you try to combat him." And a medical principle: "Illness should be well diagnosed before treatment is ordered." This is also true in research. Cracks should be prophylactically prevented as a disease and successfully fought as an enemy if one wants one's welded products to survive.

In their previous work[1] the authors prepared quite impressive statistical data concerning crack sensitivity of aircraft steels. In the second paper[2] they seem to analyze previous results and try to confirm those results with new experiments.

Weld cracking is a very serious obstacle to successful welding production. This is true not only for steels but also for other alloys as well and for aluminum alloys in particular. However, the fundamentals of the mechanism of cracking is still far from being sufficiently explored.

Hydrogen is one of the principal "villains" blamed for crack sensitivity in steels. In fact, there exists an impressively long list of accusations against this No. 1 "welding enemy." However, there exists a tendency to make only hydrogen, among all gases, responsible for cracking. Let me, however, ask this question: is hydrogen really the only gas which is guilty and are the other gases innocent? I have strong suspicions that this is not so.

As I have already mentioned[3] in the discussion to Reference 1, hydrogen is probably one, although probably the most important, among gases which contribute to cracking in steel. I believe, however, that nitrogen also has something to do with this phenomenon.

One must not forget that nitrogen is a very powerful austenite stabilizer,[4-7] and it forms hard but brittle compounds with iron, chromium, aluminum, etc. The

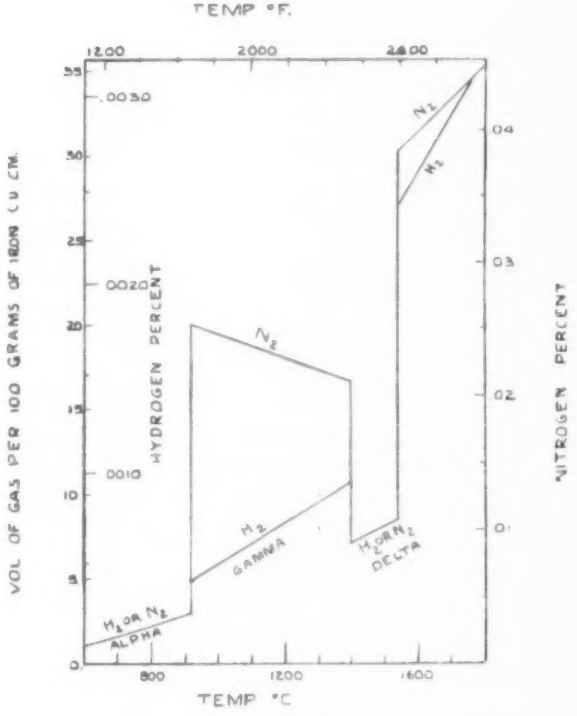

Figure 1

former property has been exploited by the Germans for production of austenitic stainless steels as a partial substitute for critical nickel. The latter seems to be used by the Russians for the production of tool steels.[8] There also exists an indication that nitrogen under certain conditions may temporarily stabilize austenite even in such steel as uncarburized AISI, 1020.[9]

There seems to exist a difference of opinion among research workers as to the solubility of nitrogen in pure iron. According to J. Chipman, Fig. 1,[10] the solubility of nitrogen in alpha and delta iron has an almost identical trend with the solubility of hydrogen, but gamma iron, especially before the gamma to alpha transformation point, may contain many times more nitrogen than hydrogen. At the melting point, similarly to the solubility of hydrogen, the solubility of nitrogen increases very rapidly and continues to increase with rising

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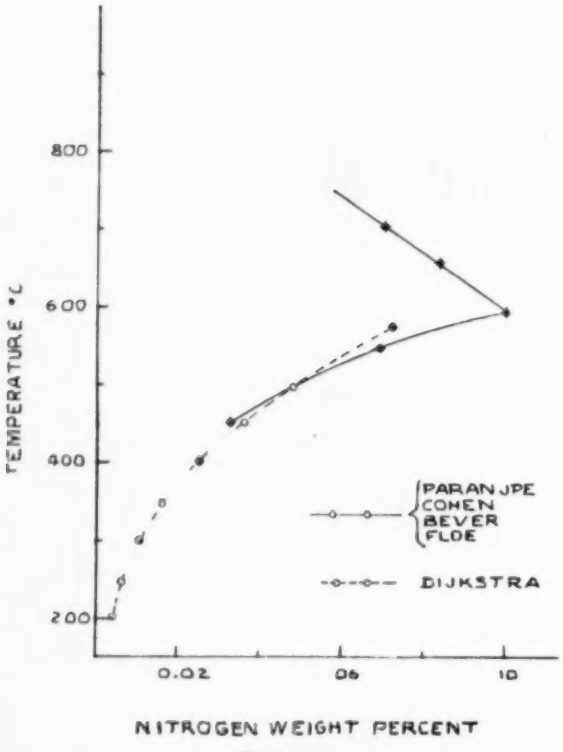

Figure 2

temperature. According to the same source[10] the solubility of nitrogen in pure iron at 600° C is only about 0.0015% while Paranjpe, Cohen, Bever and Floe (Fig. 2),[11] give this solubility as about 0.10% and Epstein[12] as about 0.01%. This solubility decreases to practically nothing at room temperature.[12, 13]

As may be seen, the solubility of nitrogen in iron varies considerably with temperature and structure. Of course, the solubility of gases is different in steels, where many alloying constituents or impurities are present, than in pure iron. Nevertheless, this gives us a general trend of the solubility.

The analysis of solubility curves indicates that the part played by gases in the mechanism of fracture may be considered in two stages. First stage of fracture may happen when relatively high gas content is precipitated in voids and cavities already present in the alloy during austenite-martensite transformation. Then, due to relatively low alloy viscosity at high temperature, atoms have quite high freedom of movement. The high aerostatic pressure may either produce fractures, if at the temperature concerned the alloy is brittle, or local plastic deformation, if the alloy is ductile or, finally, build-up more pressure until shrinkage stresses or stresses from the second stage will add to produce a crack. This crack would have rather an intergranular character.

Second-stage fracture may occur when further gas is precipitated after the temperature decreases considerably below Ar_3. Then, due to high resistance to the movement of atoms caused by the increased viscosity, gas may accumulate either in already existing gas pockets, and help to enlarge existing cracks or fissures, or produce new intergranular cracks, or it may precipitate in grain imperfections, probably on the crystallographic planes. In the latter case it may rather produce transgranular cracks or fissures.

Besides, nitrogen may stabilize austenite. In lower temperatures, when dissolved nitrogen precipitates from the supersaturated and undercooled solid gamma solution, the austenite may spontaneously transform into martensite. Austenite-martensite transformation is accompanied by a 2 to 5% increase in volume. This untempered, brittle martensite cannot yield and may cause fissures. The formation of these fissures may also be assisted by build-up hydrogen-nitrogen aerostatic pressure. This type of fissure may be inter- or transgranular depending on the location of retained austenite.

It seems that the main role of nitrogen is played in the formation of cracks in the second stage as it is unlikely that there is enough dissolved nitrogen to precipitate in any appreciable quantity during austenite-martensite transformation. There is an indication that nitrogen evolves quite fast when the temperature is slowly decreased.[14]

Another possibility of nitrogen embrittlement may be due to the formation of brittle nitride needles on crystallographic planes or iron-carbon-nitrogen eutectic.

The source of hydrogen in the weld is known. Let us ask a question: what may be the source of nitrogen? This may come from a ferrous-alloy-making process or from the air during welding. One should not forget that during welding, due to differential temperatures, there sometimes exists a very violent air draft created around the weld. This draft may be the source of nitrogen which may dissociate in high temperature and be mechanically absorbed by the molten alloy.

Much has been written about the prevention of hydrogen embrittlement. The use of low-hydrogen electrodes, avoiding humid atmosphere or draft, backing-up, etc., are rather troublesome. Perhaps tying-up hydrogen instead of preventing its dissolution in the alloy or its effusion after welding would be the easiest and the cheapest solution. It has been reported[15] that the addition of rare earths to some ferrous alloys reduces their sulfur, nitrogen and hydrogen content and improves such physical properties as impact, transition temperature, ductility, etc. They also act as grain-refining agents (probably due to high-temperature sulfide and nitride formation which may act as inoculants). They also prevent grain coarsening and hot tearing. Besides the high chemical affinity to sulfur, oxygen and nitrogen, the rare earths dissolve a very high amount of hydrogen. (See Table 1.[11])

As may be seen, at 2000° F, the solubility of hydrogen in lanthanum is over 2000 times greater than in iron; at 1650° F, 4500 times greater and at 750° F, over 63,000 times greater. Besides, in contrast to iron, the solubility in lanthanum increases with decreasing temperature.

Table I—Solubility of Hydrogen at 1 Atm.[11] (cc of H_2 per g of Metal)

Temperature, °F.	*Fe*	*La*	*Ce*	*Pr*	*Pd*
2912	...	...	...	...	0.37*
2795	0.267*	...	...	...	...
2795	0.134†	...	...	...	0.71‡
2200	0.079	...	55	...	
2000	0.054	115	113	125	0.81
1700	0.045	132	130	138	0.82
1650	0.030	135	133	140	...
1475	0.022	146	144	147	0.83
750	0.003	190	181	179	1.15
68	...	230	218	210	...

* Liquid.
† Solid.
‡ Mean.

It seems that it would be worth while exploring the potential possibility of the use of the rare earths for welding applications, with the intention of reducing ferrous alloys' crack sensitivity. Perhaps rare earths would also be the solution to crack sensitivity, porosity and bristling in aluminum alloys.

How rare earths could be applied has to be analyzed. There are many possibilities such as addition of rare earths as alloying elements to parent or filler metal, to filler metal or electrode cover, as a paste, etc.

It would be much better to prophylactically prevent cracking than to cure the weld.

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Authors' Reply

The authors are in agreement with Mr. Koziarski that the fundamentals of the mechanism of cracking are still far from being sufficiently explored.

Our studies have dealt primarily with the influence of hydrogen upon weld cracking because it appears to be the dominating factor. This has been repeatedly shown under controlled conditions wherein all other factors were held constant and the only variable was the amount of hydrogen which was permitted to become occluded in the weld deposit. In many instances the conditions were such as to preclude any possibility of picking up nitrogen or other contaminating substances.

It is not claimed that nitrogen or other materials have no influence upon cracking. We have found no evidence, however, that such influences are as powerful as that of hydrogen. These factors should not be ignored, however.

It is probable that as low-hydrogen welding methods become more widely applied, the influence of nitrogen and other substances will become increasingly important as their effects will no longer be overshadowed by that of hydrogen. The excellent paper by Rollason and Roberts[1] together with the work of Franklin[2] and others show that numerous constituents and contaminants in steel will affect the crack sensitivity. Some of these substances appear only to increase the crack sensitivity of the steel to hydrogen and seem to have little if any adverse effect in the absence of hydrogen. Whether this is generally true is not known at this time.

As stated by Mr. Koziarski there is a difference of opinion among research workers regarding the relative solubility of nitrogen and hydrogen in iron. Chipman[3] is quoted as reporting that the solubility of nitrogen is equal to or greater than hydrogen. Stern, Kalinski and Fenton,[4] however, found that 95% or more of all of the residual gas in weldments consisted of hydrogen. The latter view appears to be more in keeping with the observations of our tests.

The remarks of Mr. Koziarski regarding the possible use of rare earths and other substances to tie up hydrogen are most interesting to the authors. Certainly this line of thought deserves full consideration and it is hoped that the possibilities can be explored at some length.

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Discussion by E. C. Rollason, Ph.D., M.Sc., F.I.M., and R. R. Roberts, M.A., A.I.M.

Steinberger and Stoop suggest that our results on low-hydrogen weld deposits may have been affected by the introduction of hydrogen from steam metal reactions. However we would point out that we found no cracks in *single run* deposits from low-hydrogen electrodes, a finding which is in agreement with the results of Steinberger and Stoop. In addition, the hydrogen analyses which we reported were made on specimens quenched in exactly the same way as our

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crack test specimens. The results of these analyses show no indication of high hydrogen due to steam contamination. It is in multirun welds that we have reported cracking in low-hydrogen deposits. In such welds each bead was quenched and the beads were made in rapid succession. The explanation of this cracking given in our paper is that H_2 migrates from lower runs until a hydrogen content sufficient to cause cracking is built up. We have also reported cracking in welds from low-hydrogen electrodes, deposited completely under water. In this case the steam metal reaction will of course affect the results, and we have reported high hydrogen contents for such deposits, although cracking is less severe owing to the smaller C, N_2 and Mn contents.

Cracking in multirun welds from low-hydrogen electrodes is not likely to occur in practice, since the residual heat from previous runs will reduce the rate of cooling by the time dangerous concentrations of hydrogen are built up. Should a time interval between runs allow the dissipation of this heat, the hydrogen content will be reduced by normal diffusion to atmosphere.

Authors' Reply

The authors are appreciative of the interest shown in their paper by two such outstanding authorities as Dr. Rollason and R. R. Roberts. Our results have been in substantial agreement with theirs although the interpretation of the causes of some of these results have differed slightly.

The studies that we have made indicated that, during welding, the heated metal was sensitive to water vapor, regardless of the source. In the case of specimens welded while partially submerged it may be expected that steam is available from at least two sources: (*a*) Even with low-hydrogen electrodes there is some combined water in the coating; (*b*) steam must also inevitably arise from the water bath because of the welding heat.

With single-pass welds the hydrogen occluded from these sources would be at a minimum but as the number of passes increases the amount of occluded hydrogen from the steam metal reaction and other sources can likewise increase until the threshold of cracking is exceeded. Rollason and Roberts reported this increased cracking on multiple pass welds. There was, however, no evidence presented to indicate that the effects observed by them were due exclusively to the hydrogen contained in the electrode coating.

Measurements of residual hydrogen by the various techniques described in the literature do not always indicate the amount of hydrogen occluded in the metal during critical periods of the thermal cycle. The interval which normally elapses between the completion of welding and the measurement of hydrogen may easily influence the results. Hydrogen will escape from a weld deposit (and the adjacent parent metal) at a very high rate immediately after welding. This rate of escape will decrease rapidly with time until a state of partial or complete equilibrium is attained. The rate of escape and the final equilibrium value will be affected by many factors including postheat temperature, cooling rate, alloy composition, analysis of the surrounding atmosphere, etc. It should also be remembered that the amount of hydrogen initially introduced into the weld does not necessarily have a bearing upon the amount of residual hydrogen after a period of time because of the conditions mentioned above. Our work has shown for example that even when a weld has been made under conditions which introduce enormous amounts of hydrogen into the deposit, the final hydrogen content may be made negligible and complete freedom from cracking attained (as when proper postheating is conducted).

The authors cannot entirely agree that "cracking in multirun welds from low-hydrogen electrodes is not likely to occur in practice." It is true that the cracking tendencies of deposits from low-hydrogen electrodes are much less than with conventional types. Figure 15 of our paper shows, however, that with certain high-strength steel, welded without preheat or postheat, cracking may occur even with low-hydrogen electrodes.

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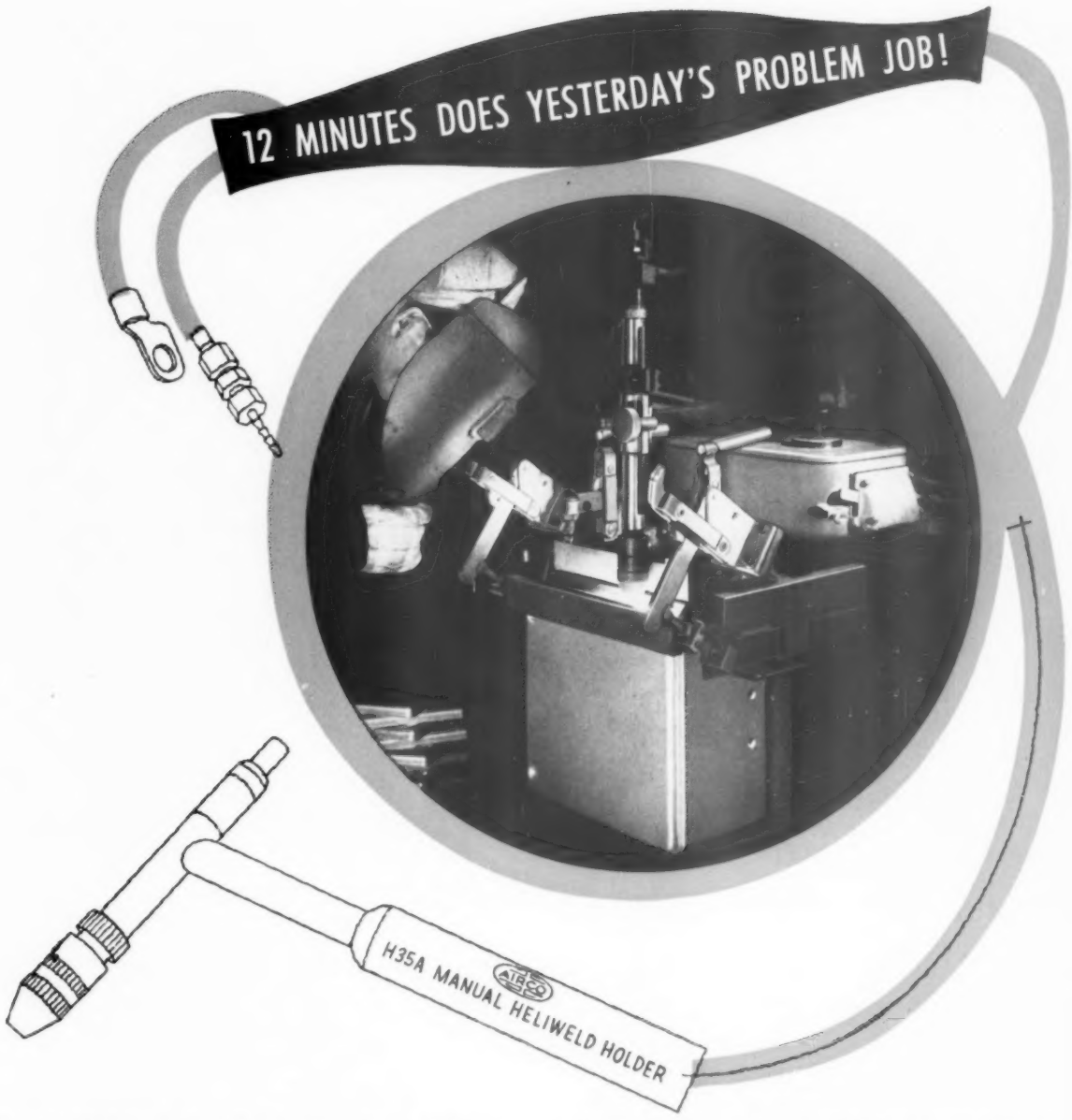

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